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TRAINING AND PRUNING

APPLE TREES

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Training and Pruning Apple Trees
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Contents

Introduction 1

Principles of Training and Pruning 2

Physiological Aspects of Training and Pruning Apple Trees 5

- Training vs. Pruning 5
- Growth Responses to Pruning Cuts 5
- Light and Tree Form 6
- Growth in the Apple Tree 8
- Filling Out the Tree Canopy 8

Training and Pruning the Young Free-Standing Tree 10

- Principles 10
- Training and Pruning 13
  - Year One (at planting) 13
  - Year Two 13
  - Year Three 13
  - Year Four and Later 15

Training and Pruning the Young Supported Tree 16

- Principles 16
- Training and Pruning the Spindle Bush and Slender Spindle 16
  - Year One (at Planting) 17
  - Year Two 19
  - Year Three and Later 20
  - Tree Training Comments 20
- Training and Pruning the Vertical Axis 22
  - Year One (at planting) 22
  - Year Two 23
  - Year Three and Later 24
- Trellis Systems 24
  - The Solaxe System 25

Pruning Mature Trees 27

- Goals 27
- Timing 27
- Control of Vegetative Vigour 27
- Crowding 28

Summer Pruning 29

Special Practices 30

- Mechanical Pruning 30
- Ripping 30
- Resetting Mature Limbs 30
- Pinching 30

Appendix A. Cultivar Adaptation Notes 31

Glossary of Terms 34

Introduction

Today, Ontario apple growers face increasing competition in the marketplace, from both other production areas in Canada and abroad. The fresh-apple market can demand well-coloured apples of uniform size, with proper maturity and satisfying flavour. Size requirements can vary. Growers must have the knowledge and tools to control fruit size development. Competition in the processed-apple market, especially from foreign producers, is also intense. To prosper in this competitive economic climate, Ontario apple growers must produce the highest-quality apples in sufficient volume for the least cost. The revenue stream back to the producer must be consistent and predictable.

Many factors influence fruit size, quality and production efficiency. Among these, tree size, shape and structure play a critical role. Tree size is a function of many factors, including cultivar, rootstock, soil, site and management practices. Tree shape and structure are largely determined by timely implementation of tree training and pruning techniques. Therefore, application of these methods, both in the early years and at maturity, is critical to cost-effective apple growing.

The choice of cultivar, rootstock, tree density and management practices will determine which training and pruning system to use. To apply these principles successfully and obtain satisfactory tree performance and productivity, it is essential to understand tree response to training and pruning. The growth habits of individual cultivars must also be well understood; see Appendix A, *Cultivar Adaptation Notes*, on page 31.

In this publication, the basic principles of tree response to training and pruning are discussed. It should be noted that these responses remain consistent, regardless of the training or pruning system used. A glossary at the end of the publication defines terms commonly used to discuss training and pruning apples.

Principles of Training and Pruning

FIGURE 1. This sequence of photos demonstrates the response of a limb when fixed to a more horizontal position in early spring. Buds that would normally leaf out have changed to fruit buds, flowered and set fruit all in the same growing season.

1. Prune to reduce tree size and stimulate growth near the cut

Pruning reduces tree size. Severe pruning increases this dwarfing effect, yet stimulates even more vigorous shoot growth near the cuts. Prune young trees to help develop the permanent canopy structure desired.

2. Emphasize the development of good scaffold limbs by training and pruning

Follow training and pruning practices that encourage well-developed and properly positioned scaffold limbs. Where an excessively upright growth habit prevails, limb spreaders or tying may be used to position scaffold limbs at a 45°–60° angle from the vertical. Positioning scaffolds at these angles eliminates the interference of lower limbs with the development of those above, helps reduce vegetative vigour, stimulates flowering and gives greater flexibility when scaffolds carry a heavy load of fruit.

The process of tying or bending limbs favours fruit bud production. Vegetative buds on a vertically positioned limb can be changed to fruiting buds by moving the limb into a more relaxed position. This phenomenon can occur over a few weeks in the prebloom period (see Figure 1, left).

However, bending limbs to near or below the horizontal virtually eliminates lateral extension growth and stimulates undesirable upright watersprouts. This technique is sometimes used in extreme conditions of tree containment. For many cultivars, fruit that hangs freely in the canopy on limbs in a relaxed, horizontal plane are less subject to limb rub marks.

3. Balance pruning and training for maximum canopy development

For 2–3 years after the tree is planted, train the tree for good canopy development, pruning as little as possible. At this stage, control the growth of the central leader and encourage the development of scaffold limbs. Excessive pruning will encourage excessive vegetative vigour and delay canopy expansion. This condition may also predispose trees to low-temperature injury and reduced flower-bud initiation, and may delay early fruit production.

4. Encourage wide-angled branch crotches

Narrow-angled crotches do not become stronger as the tree grows, because bark is trapped in the angle between the trunk and branches, preventing normal wood development in this area. The tissues in narrow-angled crotches are slow to mature in the fall and may be damaged by low winter temperatures. Narrow crotches may also offer points of entry for boring insects or disease organisms. In contrast, wide-angled crotches continue to strengthen as the scaffold limbs enlarge, permitting heavy crop loads to be carried without limb breakage.

5. Prune primarily when trees are dormant

Most pruning is carried out when trees are dormant. The ideal time for dormant pruning is in the early spring just before bud-swell. Tree wounds heal much faster when cambium is active in the spring. Orchard size permitting, delay dormant pruning past the coldest part of the winter to avoid damage from severe winter freezes. If possible, delay the pruning of young or vigorous trees until the end of the winter. It is not advisable to prune trees while the wood is frozen. If severe winter freeze has caused shoot dieback, wood discolouration or crotch injury, delay pruning until late spring when growth has started. At this time, prune back to the healthy tissue.

The term "summer pruning" usually refers to pruning after growth has started. Pruning in late spring and after the beginning of the spring flush is very debilitating to a tree and should only be done after careful consideration of the consequences. Pruning at this time stimulates excessive regrowth and inhibits flower-bud formation. Normal summer pruning is usually delayed until late July or August which, unless pruning is very heavy, usually has little effect on tree vigour and regrowth. Note that any stimulation of regrowth may adversely affect the development of winter hardiness in the fall.

6. Use heading-back or thinning-out cuts to achieve different results

Prune so the cut is nearly flush with the branch or the bud that is left to grow. Cut at the angle that exposes as small a wound as possible. Protruding stubs never heal properly and may start to decay as a result of infection from a variety of wood rotting organisms.

Essentially there are two different types of pruning cuts: heading-back and thinning-out. With a heading-back cut, only a portion of a shoot or branch is removed. Production of vigorous new shoots is stimulated immediately below the cut. When old wood is headed-back, it changes fruit spurs to vegetative shoots and initially reduces the fruit-bearing surface. This practice is especially useful in spur-bound trees, through which the total surface-bearing area of the tree may be increased in 2–3 years' time. Limbs that are headed-back become more rigid and tend to be locked in position. There may or may not be an advantage to this loss of flexibility of the pruned limb.

A thinning-out cut is used to completely remove a shoot or branch to its base. These cuts promote spur formation and improve light distribution in the tree canopy but do not disrupt internal hormonal relations. Therefore thinning-out cuts produce much less shoot growth. Figure 2, on page 4, shows severe corrective pruning of mature trees. Note that heavy limbs have been removed at the trunk to improve light distribution. Some of the water sprouts have been tied down to encourage fruiting.

7. Prune to influence the balance between vegetative growth and fruiting

Since fruit compete with vegetative tissues and roots for nutrients, heavy fruiting restricts vegetative growth, especially root growth. Pruning that removes fruit-bearing wood affects this relationship by shifting the balance away from fruiting and toward wood formation. Pruning can delay flower-bud formation and fruiting by stimulating shoot growth in the young tree. In the older tree, pruning

FIGURE 2. Severe corrective pruning of mature trees. Heavy limbs have been removed at the trunk to improve light distribution. Some of the water sprouts have been tied down to induce fruit-bud formation.

decreases cropping, thereby favouring greater allocation of photosynthates to wood development.

Heading-back cuts generally affect this balance more than comparable thinning-out cuts. The actual degree of effect on the vegetative/fruiting balance will depend on the nature and severity of the pruning job. All pruning should be minimized, yet still fulfill the desired objectives.

8. Prune with caution if tree-damaging disease is in the orchard

Pruning can sometimes result in the spread of infectious tree disease. One of the most devastating is fire blight. If fire blight is in the area, proceed with extreme caution. The probability of spreading fire blight by pruning increases with conditions that remain wet during the growing season. With fire blight, it is sometimes best to walk away, rather than prune, going back in only when there is a sustained period of dry weather. Make all pruning cuts in healthy tissue so the wound can heal properly. Remove dead and dying wood with tools that can be decontaminated if dealing with bacterial pathogens.

Physiological Aspects of Training and Pruning Apple Trees

Training vs. Pruning

Pruning is the removal of growing points, potential or actual leaf surface, and reserve materials stored in the bark and wood. For these reasons, pruning is considered a dwarfing process. Some pruning cuts stimulate vigorous shoot growth, producing the illusion of increased growth. Nevertheless, actual growth from a pruned branch is never equal to the sum total of the wood removed plus the growth it would have made.

During the early years of canopy development, concentrate on tree training, directing growth into a more permanent structure, rather than on pruning. Proper development of the central leader and scaffold limbs should be the primary objective. Establish a wide crotch angle for each scaffold limb. Where necessary, position scaffold limbs with spreaders or by tying, to direct their growth into the assigned space in the canopy. Limit pruning to those cuts needed to remove unwanted wood and to help direct growth into the canopy structure. Never consider canopy structure to be permanent. Cultivars like Gala, Fuji, Golden Delicious and Jonagold have the ability to fill gaps or holes in the canopy by the proliferation of bourse shoot growth. Cultivars that are free branching have the ability to grow fruit and new shoots carrying fruit buds from the same spur or bourse (see Figure 8, on page 9).

As the tree matures, shift the pruning program from framework establishment to the maintenance of a productive canopy. Use pruning to maintain an open canopy and retain the desirable conic or pyramidal canopy shape by restricting the spread of upper limbs in relation to lower limbs. Remove very vigorous or very weak wood to maintain as nearly uniform vigour as possible throughout the canopy. Maintain uniform light exposure within the canopy to help maintain uniform vigour. Successful training and pruning require an understanding of how trees grow, the effects of pruning cuts on tree response and proper application of this knowledge to the varied circumstances existing in the orchard.

Plan the pruning program carefully before the pruning season begins. Depending on cultivar, rootstock, site and management conditions, it may be necessary to apply a variety of pruning practices to achieve the objectives outlined above. An appropriate blend of training and pruning techniques correctly applied to the different circumstances in the orchard will help assure the production of good-quality fruit throughout the life of the orchard.

Growth Responses to Pruning Cuts

Both branch orientation and pruning affect shoot growth in an apple tree. An understanding of these phenomena is basic to the development of an appropriate pruning program. In apple trees, upright (vertical) branches are strongly vegetative and exhibit extensive terminal-shoot growth (see Figure 3, below). The amount of lateral branching will depend on cultivar and tree vigour but is often sparse in upright limbs. Orientation of such a branch to a near-horizontal position will decrease the dominance of terminal growth. As terminal growth is reduced,

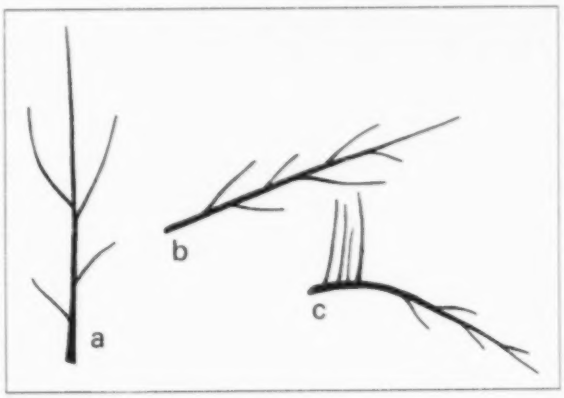


FIGURE 3. Response of branch growth to limb orientation. (a) Vertical branches produce vigorous growth. (b) Vigour is reduced, secondary branching is improved and flowering is stimulated in limbs positioned near the horizontal. (c) A limb oriented below the horizontal position grows weakly, but suckering is stimulated near the point of bending. This growth is also called "reiteration."

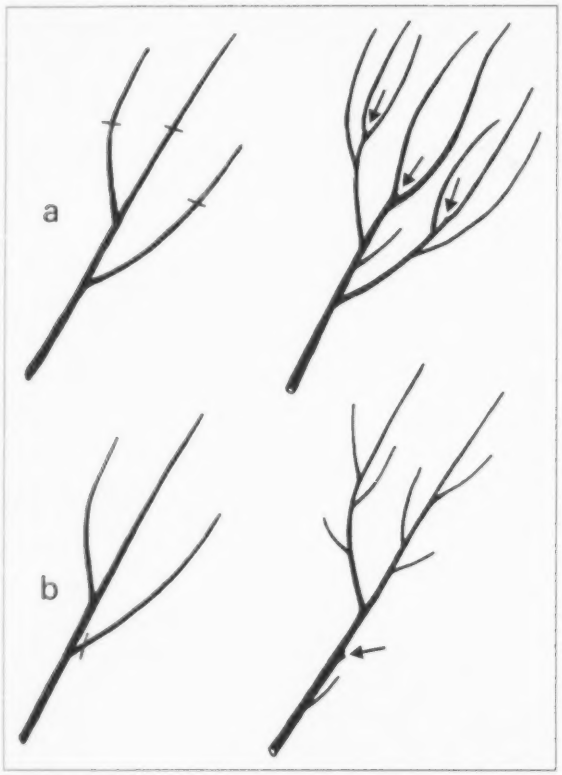


FIGURE 4. Effects of (a) heading-back and (b) thinning-out cuts. Heading-back stimulates strong vegetative growth and delays flowering. Thinning-out has only a modest stimulating effect on growth.

overall branch vigour is also reduced. More lateral branching will occur in a branch that is nearly horizontal, and these lateral shoots will tend to be less vigorous and more fruitful. In addition, proper branch orientation stimulates flower-bud formation and early fruit production. When a branch is oriented with the tip below the horizontal position, terminal extension virtually ceases. Apical dominance is lost and growth tends to be concentrated in a series of vigorous, upright shoots that develop near the point where the branch is bent.

Pruning cuts can be divided into two convenient categories — **heading-back** and **thinning-out** (see Figure 4, above). A heading-back cut removes a portion of a branch in the vicinity of a bud or spur. In contrast, a thinning-out cut removes an entire branch section at its junction with the remainder of the branch.

Heading-back cuts interrupt the flow of natural growth regulators in a branch. This change induces

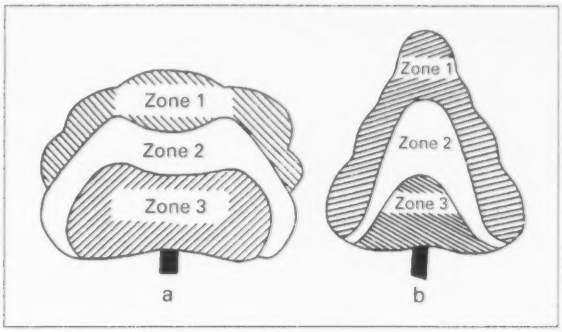


FIGURE 5. Distinct zones of light exposure form in the canopy of an apple tree due to shade cast by the canopy itself. (a) A globular canopy shape produces much more internal shading (Zones 2 and 3) than (b) a conic shape.

several buds near the cut to initiate vigorous vegetative growth. The actual amount of vegetative growth, however, depends both on the inherent vigour of the branch and its orientation.

The heading-back of an upright branch produces a substantial increase in shoot growth near the cut as well as farther down on the branch itself. In a near-horizontal branch, a heading-back cut does not alter vegetative growth as much but stimulates more of the potential shoot growth near the cut. Similarly, a heading-back cut in a branch oriented below the horizontal position increases vegetative growth near the point of the cut, with little effect on overall growth.

Thinning-out cuts have a relatively minor effect on the hormonal system of a branch. For this reason, a thinning-out cut usually produces a relatively small response in vegetative growth, regardless of branch orientation.

Light and Tree Form

The energy source for tree growth is light, which is absorbed by leaves. Light is not only important for carbohydrate production, it also stimulates flower-bud formation and induces colour development in the skin of the fruits. Since each apple leaf absorbs approximately 90% of the radiation to which it is exposed, upper leaves tend to receive more light than lower leaves, which are shaded. This produces several distinct zones of different light exposure in the tree canopy (see Figure 5, above). In Zones 1 and 2, light levels are at or above what is needed for maximum photosynthesis, flower-bud formation and the

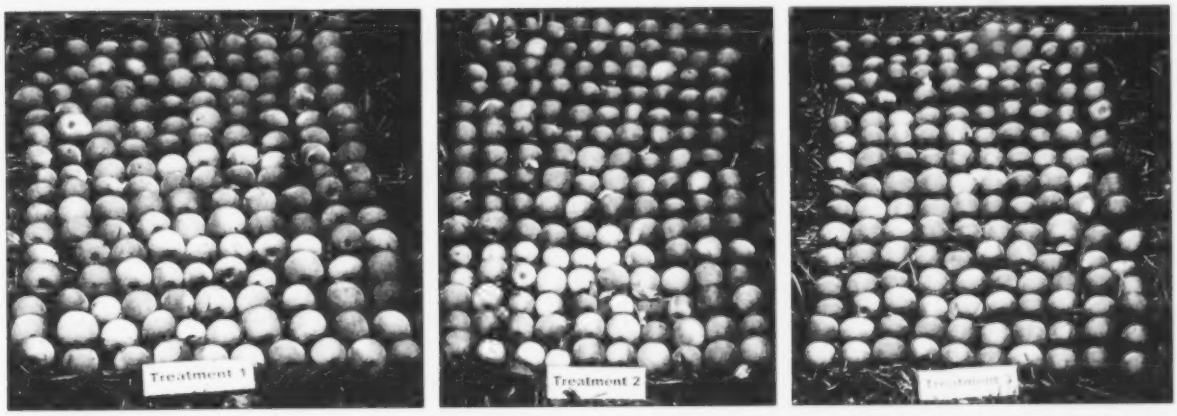


FIGURE 6. Samples represent 150 fruit taken from individual representative mature Fuji/M.7 trained as central leader trees having: (Treatment 1) no pruning in either the dormant period or during the summer; (Treatment 2) dormant pruning coupled with summer pruning; and (Treatment 3) dormant pruning, summer pruning and a reflective mulch laid 2 months before harvest. Individual fruit are positioned as they were harvested from the tree going from the bottom to the top. Fifty apples were selected at random from the bottom of the tree, 50 from the middle and 50 from the top. In these photos, the apples that look whitish lack colour development. Colour versions of these photos appear on the back cover.

development of good fruit size and colour. When light levels in the canopy fall to below 30% of full sun (Zone 3), flower-bud formation is reduced, spur vigour is lost and any fruits that develop are of poor colour and small size. After several years of exposure to low light levels, the weakened spurs and shoots in Zone 3 usually die or are removed completely, and production from the interior of the tree is lost. Tree size has a significant effect on the amount of poorly illuminated leaf area within the canopy of an apple tree. The zone of inadequate light can vary from as much as 25% in a large, standard-size tree to as little as 8% or less in a dwarf tree.

Trees planted into bed systems of 2 or 3 rows or as super spindles can be highly productive early in the life of the orchard. However, any advantage with this system can quickly be lost if shading becomes unmanageable as the planting matures.

In addition to tree size, the shape and structure of the canopy significantly affect light distribution within a tree. A globular canopy shape, typical of most standard trees, causes substantial in-tree shading (Figure 5a, page 6). A conic or pyramidal shape, with the upper limbs restricted in spread relative to the lower limbs, produces the most favourable light distribution (Figure 5b, page 6). This structure minimizes in-tree shading from above. The conic shape has the additional advantage of maintaining the majority of the canopy volume closer to the ground, which permits easier pruning, spraying and harvesting operations. For these reasons, the conic tree shape is preferred for freestanding trees where canopy structure is not dictated by a specific support system.

A conic tree shape requires a central leader for support of the fruiting limbs. It also requires a system of fruiting scaffold limbs distributed both vertically along and circumferentially around the leader. The upper limbs are not permitted to overgrow and therefore shade the lower part of the canopy. Such conic trees will permit maximum light penetration throughout the canopy.

An open tree structure contains well-spaced scaffold limbs with a minimum amount of upright growth, leaving considerable open space for light channels into the canopy. This structure provides better light distribution, minimizing the zone of inadequate light penetration. It also enhances spray distribution and access to fruit at harvest time.

Fuji is an example of a cultivar that is highly dependent on light distribution for colour development. Poor pruning practices will quickly result in lack of colour development in the lower portions of the canopy. Figure 6, above, reveals what can result from three light management treatments when producing a high colouring strain of Fuji on mature trees.

TABLE 1.
Effect of Fruit on Growth of Vegetative Components of Apple Trees Compared to Growth of Defruited Trees

Tree component	Percent reduction in annual new growth of component brought about by fruiting
Leaves	–30
New shoots	–35
Structural wood (branch and trunk thickening)	–48
Roots	–76

Source: Maggs, 1963. *Journal of Horticultural Science* 38:119–28

TABLE 2.
Effect of Tree Size on Distribution of Photosynthetically Produced Dry Matter Among Above-Ground Components of McIntosh Apple Trees

	Percent of total annual above-ground dry-matter increase contained in component	
Tree component	Large tree (seedling rootstock)	Semi-dwarf tree (M.7 rootstock)
Leaves	14	9
New shoots	4	2
Structural wood (branch and trunk thickening)	37	12
Fruit	45	77

Source: Forshey and McKee, 1970. *Horticultural Science* 5:164–65

Growth in the Apple Tree

In the spring, before a large leaf area has developed, the tree is still dependent on stored resources from the previous year. However, shortly after shoot growth begins, the leafy canopy develops sufficiently to meet all the carbohydrate requirements of the tree. The expansion of shoots and leaves, the enlargement of fruits, the thickening of branches and the trunk, and the development of roots are all growth processes supported by the products of the leaves. Spur leaves also play a vital role in providing photosynthates to fruitlets going through the cell division and early cell expansion stages of growth.

Since many different parts of the tree are in active growth simultaneously, growing points compete with one another for carbohydrates. Actively growing fruits divert carbohydrates away from other growing points, reducing all forms of vegetative growth and thereby contributing to control of tree size (see Table 1, above). However, these reductions in vegetative growth of different parts of the tree are not equal. The growing points farther away from the leaves are farther apart, illustrating the competitive interaction among growing points for carbohydrates. Although shoot growth is the most visible form of vegetative growth in a tree, other less visible forms have a much greater influence on tree productivity. A large, standard tree may devote about the same amount of its total seasonal resources to growth of woody tissues as it will to fruit (see Table 2, right). Shoot growth, however, accounts for only a very small fraction of the total seasonally fixed dry matter. The effect of tree size on growth allocation among growing points illustrates the significance of structural wood in determining production efficiency. Smaller apple trees direct a much higher proportion of their dry matter production into fruit because of the absence of a large quantity of structural wood. Therefore, not only do smaller trees have better light distribution and a more easily managed canopy, they also direct a much higher percentage of their resources into fruit production. Consequently, many apple growers are rapidly changing from large to small trees on recommended dwarfing rootstocks.

Filling Out the Tree Canopy

One of the least-understood growth habits of apple trees is their ability to send branches bearing fruit buds into an empty space in the tree canopy that is well-exposed to light. These branches can come from fruiting spurs or generative wood. The ability of a tree to make a branch from what appears to be a dead end in growth is one of the secrets to a strong fruiting canopy.

Fruiting branches can start out as obscure buds. These buds in many cases can have their origins on the side of a spur or dard and develop into shoots that eventually become fruit-bearing branches.

Branches do not necessarily come from vegetative buds on non-fruiting wood. Figure 7, on page 9, shows a well-formed dard that has a fruit bud on top that will flower and produce fruit during the current growth season.

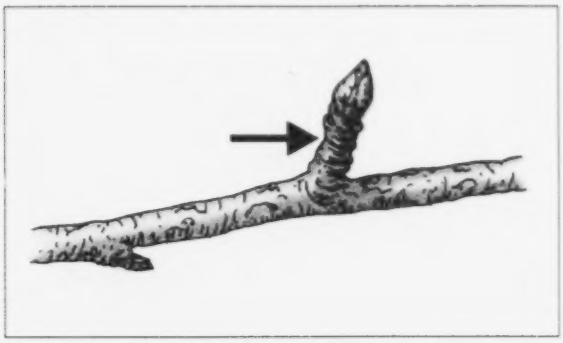


FIGURE 7. Dard arising off a 1-year-old branch and terminating with a fruit bud. The arrow shows the area just under the bud that will likely swell to form a bourse that will send out a shoot shortly after the bud flowers.

FIGURE 8. Both fruit and a newly formed bourse shoot shown growing from the same spur during the month of July. The shoot will likely end in a fruit bud as it matures.

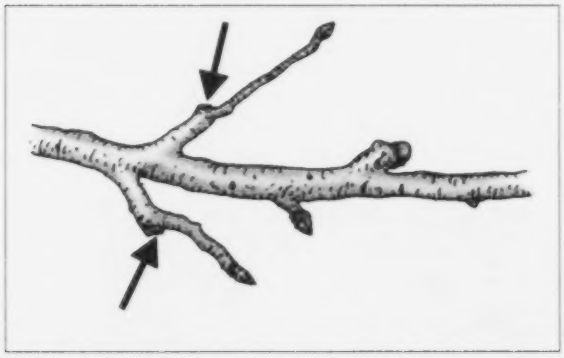


FIGURE 9. Two bourse shoots in the dormant season. Both shoots have come from a bourse or cluster base at the same time the spur is producing fruit. The bourse is the thickened or swollen stem that develops at the base of the flower cluster. The arrows point to the fruit stem scar.

FIGURE 10. Mature branch arising from original dard by way of a bourse shoot. Any evidence of that original bud has long since disappeared.

Sometime in June of the same year, the area just below the flower truss can, depending on the cultivar, swell and become a bourse. From the side of this, a bourse shoot can arise and produce a branch that could itself end in a fruit bud in the same year.

Until recently, notching branches with a saw was a popular way of stimulating branch formation into blind spots in the tree canopy. What was not fully understood at the time was that the tree would likely fill the space anyway and probably a lot faster without this costly practice.

Gala is an excellent example of a cultivar with the ability to demonstrate this trait. Figure 8, right, shows the fruit and the newly formed bourse shoot during July. The fruit and bourse shoot will both grow from the spur at the same time.

Figure 9, left, shows two bourse shoots that carry fruit buds at their ends. The stem scar from an apple grown the past season is visible at the base of the bourse shoot.

If you look at a branch that comes from the original dard, it could look like Figure 10, above, in 3–4 years. Over that period of time, fruit buds at various positions on the branch will have helped fill bins in the orchard.

Training and Pruning the Young Free-Standing Tree

Principles

Two requirements are necessary to develop the conic-shaped canopy of a free-standing tree. First, develop a strong, upright central leader that is capable of supporting the fruiting canopy. This central leader must reach a height sufficient to permit scaffold limbs to fill the assigned space in the orchard. Second, develop a series of correctly positioned and well-structured scaffold limbs from the central leader to fill the assigned space with fruiting wood.

Where possible, in the early years, concentrate on training and directing growth into the desired canopy structure. Limit pruning to removal of unwanted, broken or damaged branches. The specific training and pruning requirements will vary from year to year depending on the cultivar, rootstock and tree vigour. Since scaffold limbs rarely develop in an ideal position for optimum light exposure and heavy fruit production, every effort should be made to establish wide crotch angles, spread scaffolds and develop secondary branches and fruit spurs. Some cultivars, such as Empire and Idared, produce a spreading canopy that requires minimal additional training. Cultivars such as Delicious, McIntosh, Spartan and most spur-type strains tend to produce vigorous upright growth. In such trees, extensive efforts are required to establish an acceptable canopy structure and shape.

While precocity (early cropping) is a common feature today among cultivars on dwarfing and semi-dwarfing rootstocks, excessive early cropping withdraws carbohydrate resources from vegetative growth and may even force the scaffold limbs or the leader out of position. Uncontrolled early cropping can seriously distort tree structure, prematurely restrict vegetative growth, interfere with the continued development of the canopy and reduce overall fruit quality significantly. Factors including soil quality, irrigation and overall tree quality from the nursery enable the grower to crop heavier in the establishment years.

1. Develop the Central Leader

Establishment of the central leader begins at planting and continues until the tree reaches its final height. Apply the following two-step process each year to assure strong, upright central leader development.

1. Head-back the leader shoot each spring by removing about one-quarter to one-third of its length. Heading-back the central leader during the dormant pruning period forces the vigorous growth of several upright shoots from the buds adjacent to the cut. The growth of these shoots causes the natural production and downward movement of auxin hormones. These hormones stimulate lower lateral shoots to form a wider crotch.

2. Once the vigorous, upright shoots originating from the central leader have reached 10–15 cm in length, select a single shoot to continue the central-leader formation and remove the others (see Figure 11, below). At this stage of development, these shoots can be cut out easily with hand shears. Manual removal may seriously damage the remaining leader. Removal of competing upright

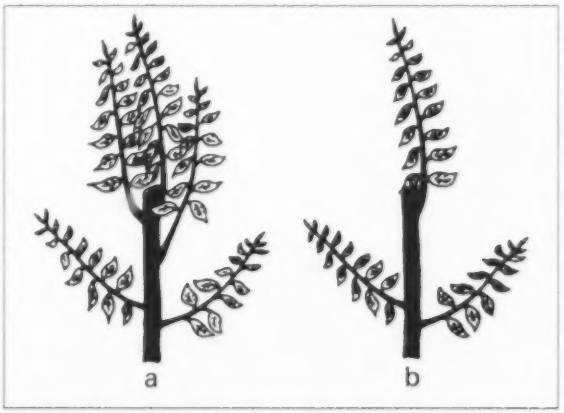


FIGURE 11. (a) Heading-back the central leader stimulates strong vegetative growth but does not produce a single dominant shoot. (b) Leader selection removes competing upright shoots, assuring leader dominance and enhancing development of scaffold limbs.

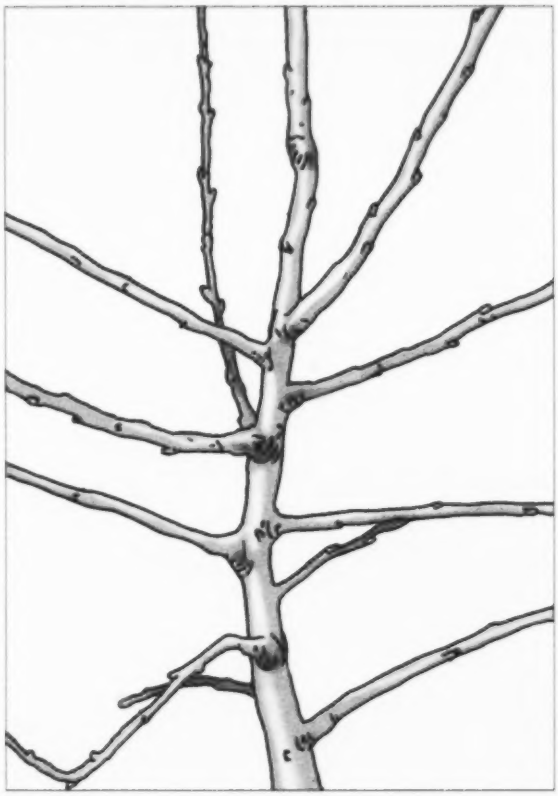


FIGURE 12. The effect of vigorous growth on crotch angles following heading-back of the central leader. The leader was headed while dormant and leader selection carried out at the correct time. Note the continued dominance of the central leader and strong growth of scaffold limb candidate shoots below.

shoots from the leader not only helps maintain its dominance but also permits better development of the lateral shoots below, which will become the future scaffold limbs (see Figure 12, above). Continue this process of leader management until the trees reach their intended height.

2. Select the Scaffold Limbs

Selection and development of the scaffold limbs is the most important process in the training and pruning of a young apple tree. Strong, well-formed scaffold limbs are the key to an efficient tree shape and to heavy fruit production. The process begins with the formation of wide crotch angles (see Figure 13, right). A wide crotch angle for scaffold limbs is essential to support heavy crops of fruit at maturity. A narrow crotch contains a bark inclusion. This structure represents a point of weakness and also permits decay organisms or other pests to enter the tree tissue. Limbs with such

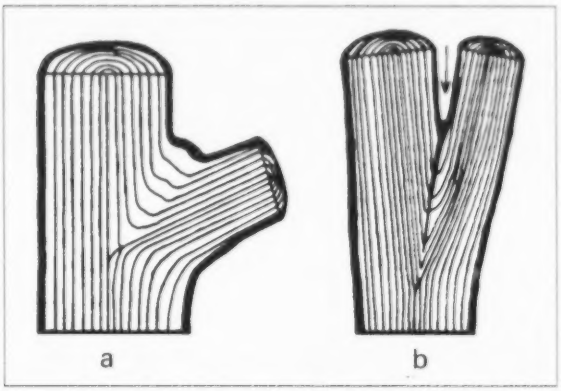


FIGURE 13. Structure of (a) wide and (b) narrow crotches. The narrow crotch is structurally weak and contains bark inclusion (arrow), an entry point for insects or diseases (modified from *Cornell Agr. Expt. Sta. Bull.* 419, 1923).

crotches often break when heavily loaded with fruit. In contrast, a wide crotch angle continues to strengthen as the scaffold limb enlarges, permitting heavy fruiting without limb breakage.

Ensure that the lowest scaffold limb is at least 60 cm above the ground to permit orchard equipment to pass without causing damage to the tree; remove any lower growth. Separate scaffold limbs in the first tier from each other vertically on the trunk by at least 10–20 cm and orient them toward different quadrants in the space assigned to that tree (see Figure 14, below). A full tier of scaffolds contains three or four limbs well distributed around the

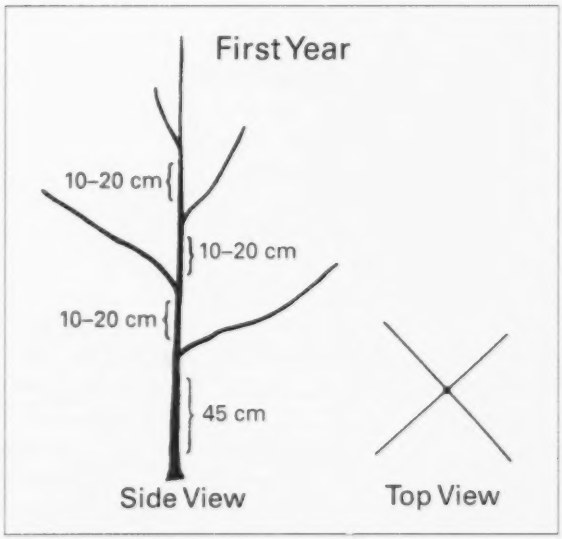


FIGURE 14. Selection of scaffold limbs during the first year in the orchard.

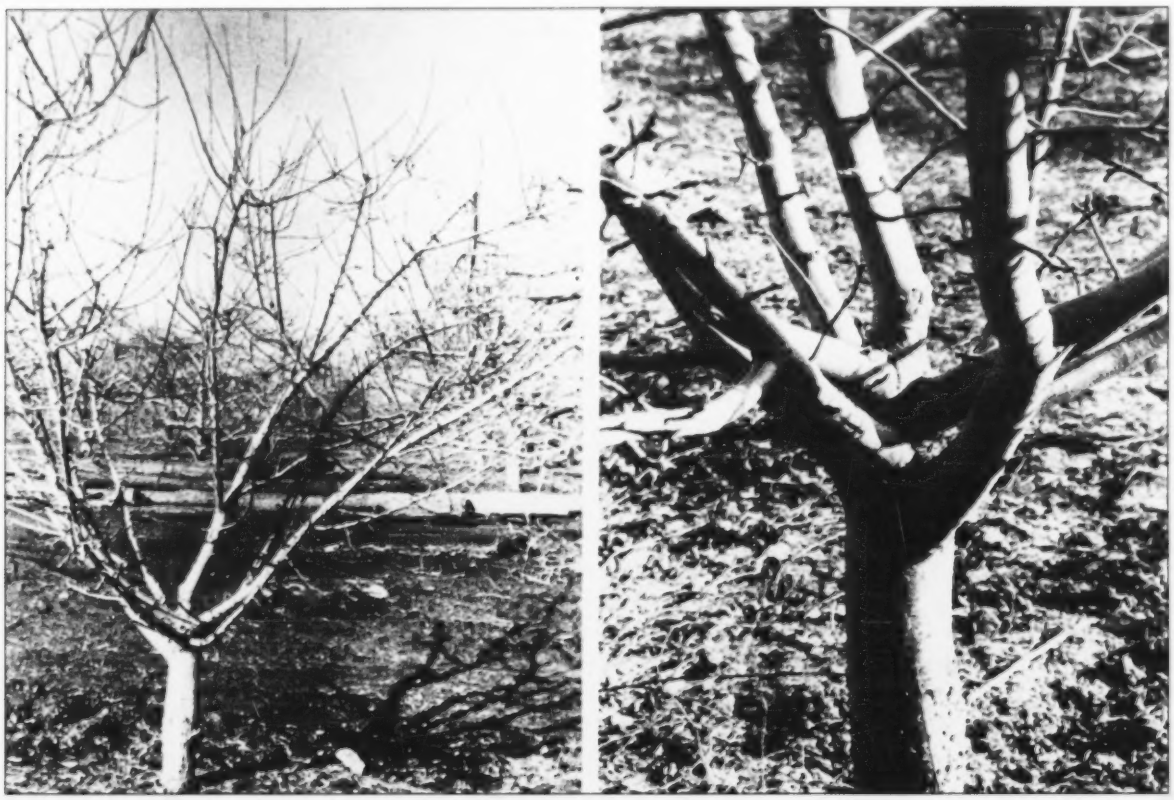


FIGURE 15. This tree has no dominant central leader because the many closely spaced scaffold limbs have interrupted the vascular connection to the leader. The result is a globular canopy shape.

trunk. It is important that scaffolds are not positioned very close together on the tree trunk. When this situation occurs, the growth of the scaffold limb bases may restrict the flow of nutrients to the central leader, thereby weakening it. Loss of central leader dominance will result in the formation of an undesirable globular canopy (see Figure 15, above).

As the tree develops, additional tiers of scaffolds are selected so that the limbs intersect the quadrants occupied by scaffolds in the tier below (see Figure 16, right). Separate each tier of scaffold limbs from the tier below by at least 20 cm, and space each new scaffold limb vertically from its nearest neighbour by 10–20 cm as described previously. A minimum distance of 60–100 cm should separate scaffold limbs directly above one another. This approach assures sufficient space between scaffold limbs to allow good light penetration within the canopy interior and easy access to the fruit at harvest.

Vigorous vegetative growth should be maintained in the lower scaffold limbs so that upper scaffold limbs do not extend beyond the lower limbs, thus increasing interior shading. Spread the scaffold limbs

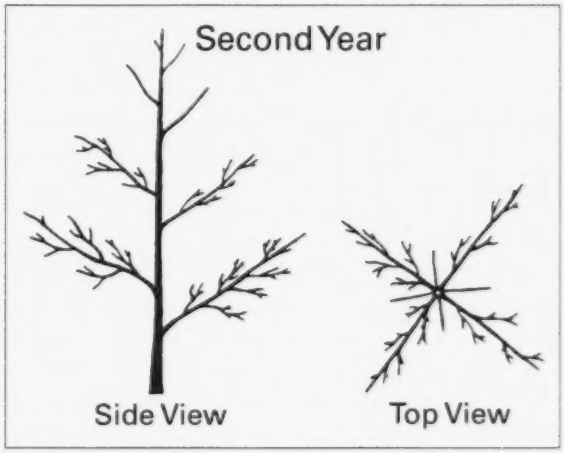


FIGURE 16. Selection of scaffold limbs in the second year in the orchard. Upper scaffold limbs should bisect quadrants occupied by lower scaffold limbs to avoid overlap.

of cultivars that tend to produce very upright growth. This process usually begins in the second year of growth in the orchard. The important beneficial effects of limb spreading include:

- helping maintain the dominance of the central leader by controlling vegetative vigour
- preventing interference from lower scaffold limbs in the development of scaffolds higher in the tree
- favouring improved lateral bud break, spur formation, lateral branching and flowering
- enhancing early productivity and improved fruit quality
- improving crotch angle and structure.

Limbs should be positioned no more than 45°–60° from the vertical position. This will prevent formation of upright watersprouts and allow for some limb flexibility when heavy crops of fruit are produced. If the limb is spread too far, fruiting will cause the limb to bend below the horizontal position, virtually eliminating extension growth and creating the possibility of excessive upright watersprout formation.

Training and Pruning

Year One (at planting)

Immediately after planting but while it is still fully dormant, head-back the tree to stimulate vegetative growth and bring the shoot into balance with the root system. For a normal one-year whip, use a heading height of 75–90 cm. Remove all lateral shoots, unless there are at least three well-formed laterals of approximately equal size with wide crotch angles, properly positioned along the trunk to become effective scaffold limbs. Head-back two-year-old or well-feathered trees to a vegetative bud to stimulate growth. On such trees, any shoots not intended for scaffold limbs should be removed. Either remove completely or head-back any lateral shoots that are considerably larger than the rest to bring them into balance with the others.

Once shoot growth has begun, select a single central leader as described in the section *1. Develop the Central Leader*, on page 10. Remove all shoots less than 60 cm from the ground. Some shoots with the potential to be scaffold limbs will emerge with narrow-crotch angles. This condition can be corrected by using round toothpicks or clothespins

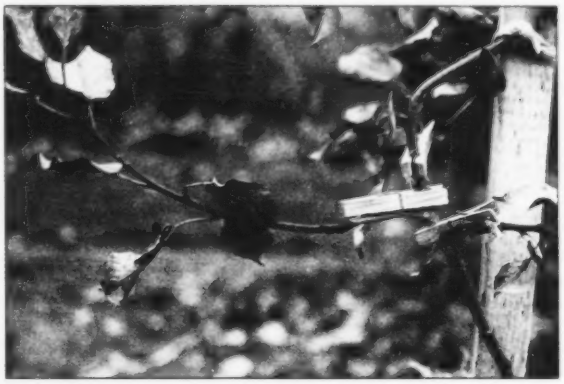


FIGURE 17. Clothespins have been used on this young Honeycrisp™ tree to increase the crotch angle of newly emerged shoots. The clothespins were installed when the new shoots were approximately 10 cm long and actively growing.

to widen the crotch angle (see Figure 17, above). Remove any flowers present as soon as possible. Do not prune any more during this first growing season.

Year Two

During the dormant pruning season, head-back the central leader by one-quarter to one-third to stimulate continued strong vegetative growth (see Figure 18, on page 14). Select scaffold limbs in the first tier according to the criteria described in the section *2. Select the Scaffold Limbs*, on page 11. Remove lateral shoots with narrow crotch angles or other characteristics undesirable for the permanent canopy structure. The heading-back of scaffold limbs is not generally recommended in non-fruiting trees. With cultivars such as Idared, terminal flower buds are common and may be removed during pruning. In cultivars with upright growth, such as Delicious, spread scaffold limbs to 45°–60° from the vertical position. Take care not to position scaffold limbs near or below the horizontal.

With many cultivars, flowers may form on the leader and new scaffold limbs; these must be removed to prevent excessive early fruiting. Flowers or fruitlets can be removed by hand or by chemical means. If chemical removal is used, carefully examine trees and any remaining fruits removed by hand afterwards for signs of damage.

Year Three

To maintain a dominant central leader, repeat the leader management process described in the section

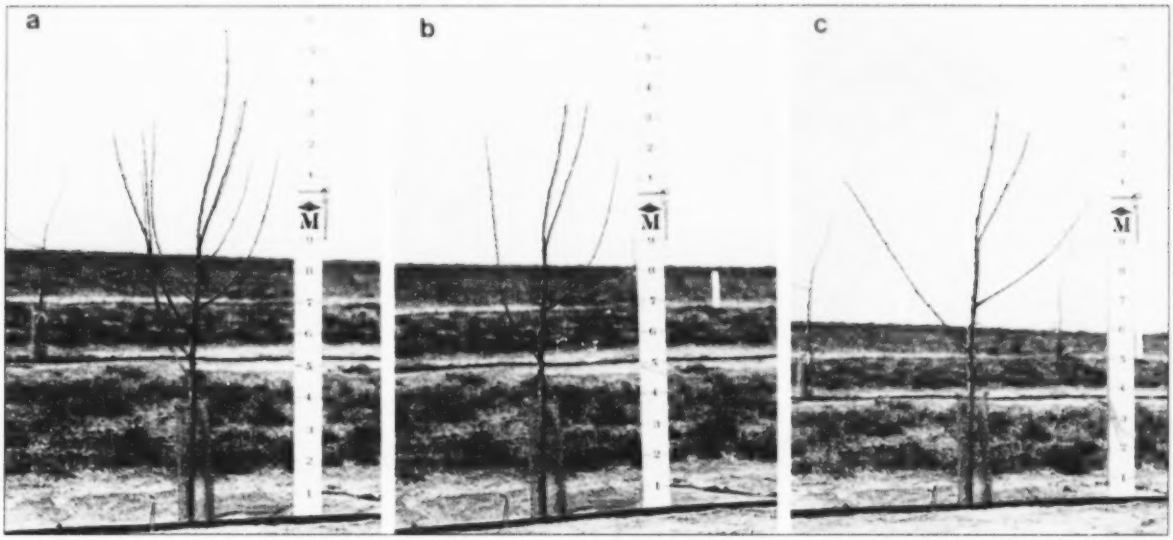


FIGURE 18. One-year-old Red-Spur Delicious / MM.106 tree in early spring of the second year in the orchard, showing (a) heading-back of central leader, (b) selection of scaffold limbs and (c) positioning.

1. Develop the Central Leader, on page 10. Choose additional scaffold limbs following the criteria described in the section *2. Select the Scaffold Limbs*, on page 11. As far as possible, choose limbs that do not overlap those below and are separated from the first tier by at least 20 cm (see Figure 19, below).

Where tree growth has been exceptional, limited fruiting may be allowed in the third season. However, carefully control early fruiting to avoid serious weakening of vegetative growth. Only allow fruiting on those scaffold limbs physically capable of carrying fruit. Do not permit fruiting in the upper

FIGURE 19. Pruning and scaffold limb selection in 2-year-old Empire/M.26 trees.

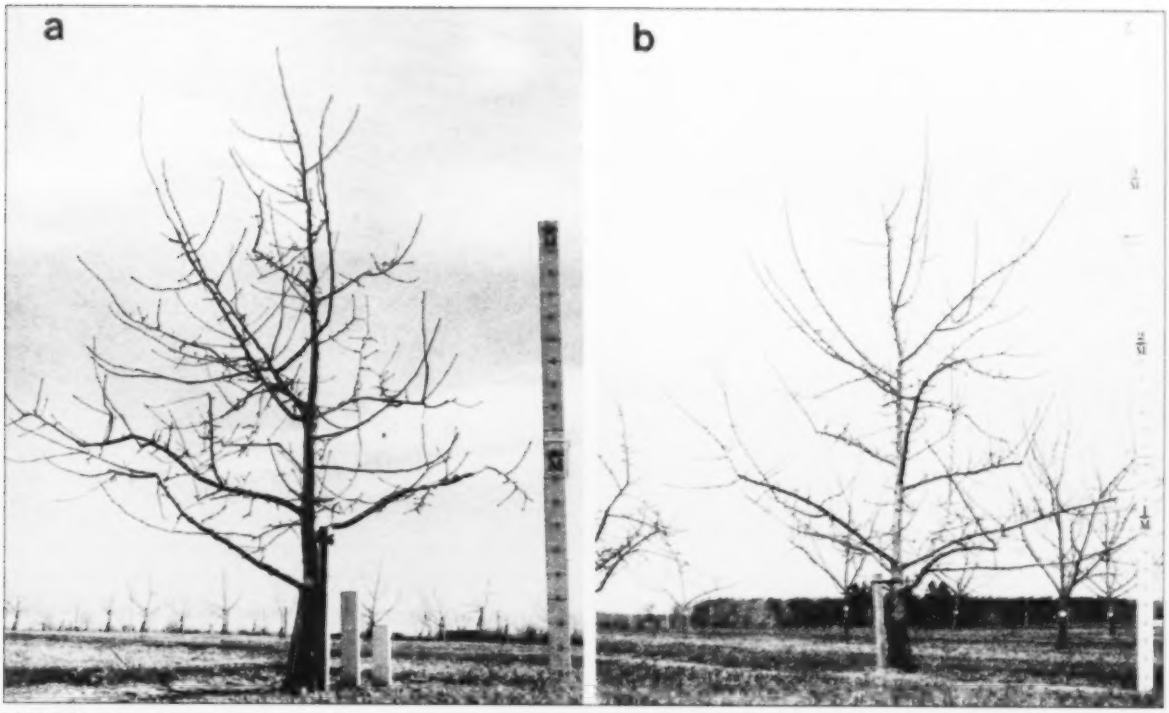


FIGURE 20. Results of good training and pruning practices are illustrated by (a) 5-year-old Idared and (b) Empire trees on M.26 rootstock.

parts of the tree or on the leader. If the tree is not large enough to carry a crop sufficient in size to pay for the additional spray and harvest costs, remove the entire crop and allow vegetative growth to continue without interference.

Year Four and Later

Continue central leader and scaffold limb management as described in the section *Principles*, on page 10, until final tree height is achieved. By the fourth season, most young trees are ready to carry a small crop of fruit. Again, control fruiting so that continued vegetative growth is not jeopardized. Careful crop load adjustment, probably necessitating some hand thinning, is essential. As cropping levels increase, extension growth of the lower scaffold limbs may diminish. If this condition develops before the lower scaffold limbs have filled their assigned spaces, it may be necessary to head-back the terminal extension shoot on each limb to maintain adequate vegetative growth. A combination of appropriate thinning-out and judicious use of heading-back cuts when required should assure continued vegetative development. Ensure that upper scaffolds are not allowed to extend beyond the lower limbs. Attention to these details will result in the development of an effective canopy structure (see Figure 20, above).

Training and Pruning the Young Supported Tree

Principles

> Train trees supported temporarily but intended to be free-standing or those supported only by a trunk stake according to the same principles described for freestanding trees.

Fully supported trees are normally planted at higher densities. Full tree support permits considerable variation in canopy shape, which is limited primarily by the nature of the support system employed (see Figure 21, below). For this reason, training and pruning practices for supported trees may vary substantially from those for free-standing trees.

A dominant central leader is less important for a supported tree. In such cases, a pole or trellis provides support. Since a strong central leader is not necessary, heading-back the leader should be avoided. Where leader growth is excessive, the leader shoot may be removed and a weaker lateral branch left unpruned and trained in its place. This helps control the vigour of the upper part of a supported tree.

In high-density supported orchards, the amount of vegetative growth must be closely controlled. It is very important to select and position scaffold limbs to enhance early fruiting on the tree. Scaffold limb selection should be based primarily on the distribution of limbs around the tree or the position on the leader relative to the support system. The vertical distance between scaffolds is less important since the canopy will be small, but an open structure should still be maintained. Normally upright cultivars require considerable limb positioning or tying to the support system to achieve heavy early fruiting. The emphasis in high-density plantings should be on the stimulation of early fruiting to control vegetative vigour. Heading-back cuts should be largely avoided. Any unnecessary stimulation of vegetative growth can quickly lead to crowding and excessive shading within the canopy. Exposure of fruit to maximum light contact is always a priority for large, well-coloured fruit.

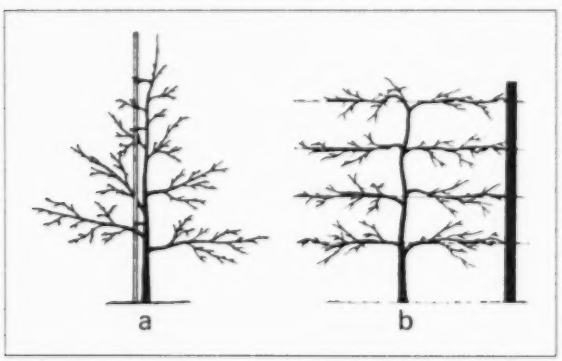


FIGURE 21. Trees may be supported by (a) an individual pole or (b) a trellis system. Many variations in tree shape and support structure are possible.

High-density supported systems require physical support for the life of the planting (perhaps 18–20 years). If not already in place, the support system should be put in **immediately** after planting. Do not allow the trees to stand free, as this will lengthen the time to establishment and reduce the amount of extension growth possible. There are major differences in the growth and fruiting habits of apple cultivars. No single training system will be perfect as a result. As grower experience increases, different systems will prove best for different cultivars (see Appendix A, *Cultivar Adaptation Notes*, on page 31). The ultimate yield potential of a block will be determined by the size of canopy-bearing surface.

Training and Pruning the Spindle Bush and Slender Spindle

The slender spindle (SS) form of tree training is a narrower version of the spindle bush. Both can be trained on the same principle. A slender spindle tree consists of a moderately strong central leader surrounded by weaker and more or less horizontal lateral branches. The diameter, length and vigour of these branches decrease slightly from the base to the top of the tree. The general appearance is that of a slender bell in which the basal diameter is approximately half of its total length (height). In developing the slender spindle tree, the goal should always be to weaken the growth in the top of the tree

in order to encourage the production of fruiting laterals. As with all training systems, you must build the tree one step at a time. A high level of grower skill and considerable labour is required to be successful with the SS system.

Year One (at Planting)

Immediately after planting, and while it is still dormant, the tree must be pruned. If a "whip" has been planted, make a heading-back cut at 80–90 cm from the ground. Once the whip has been pruned, bag the leader of the whip to encourage maximum limb development.

Bagging

Immediately after heading the tree at planting, place an approx. 50-cm long plastic bag over the terminal and secure it in place using 2 or 3 twist ties. This will encourage maximum branch initiation. The bag is removed at the ½-inch green stage or before any scorching of new growth occurs (7–14 days). Under bright sunny conditions, remove the bag in the evening to reduce the possibility of burning tender tissues.

Head-back spur types and weaker whips slightly lower (70 cm from the ground); vigorous varieties can be left a little higher (95 cm from the ground).

If a "feathered" tree (a tree whose shoots are the same age as the stem from which they originate) is planted, remove all feathers below 60 cm above the ground and any that are too vigorous or have bad angles. Any feathers longer than 40 cm should be cut back by one-quarter to one-third of their length. All remaining feathers should be of nearly equal diameter. If four or more useful feathers remain, head the leader 20–25 cm above the highest useful feather (see Figure 22, right). If less than four well-spaced feathers remain, remove them all using a "Dutch cut" (see Figure 23, right) and handle the tree like a whip. If the feathers are badly located (for instance, all to one side on the stem), they should all be removed with the Dutch cut.

Leader Development

When the shoots resulting from heading the leader are 7–10 cm long, select the leader and neatly cut off the 2 or 3 shoots competing with it. You may also use the technique described in the sidebar *Pinching Technique*, on page 23, and Figure 35, on page 23.

FIGURE 22. Photo of a feathered nursery tree taken Aug. 3. All the growth from the bud union up has taken place since the previous May. Scheduled waterings enhance the growth and development of nursery stock.

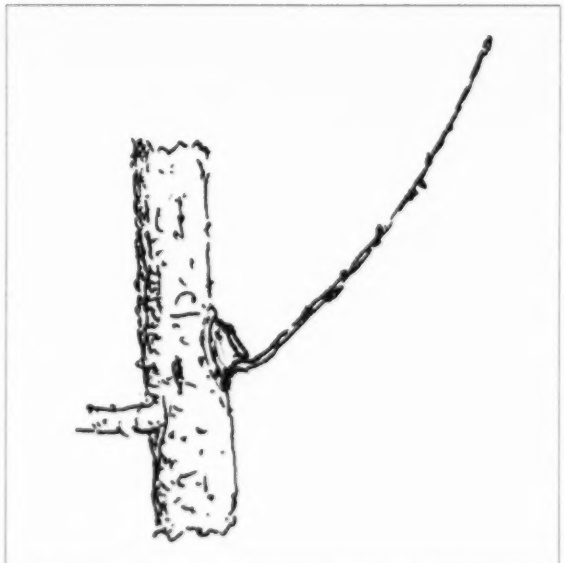


FIGURE 23. A Dutch cut is made when a limb is removed on an angle and not flush with the trunk. The cut is close on the top and wide on the bottom to encourage latent buds to grow a usable limb at the location where an unusable one was removed.

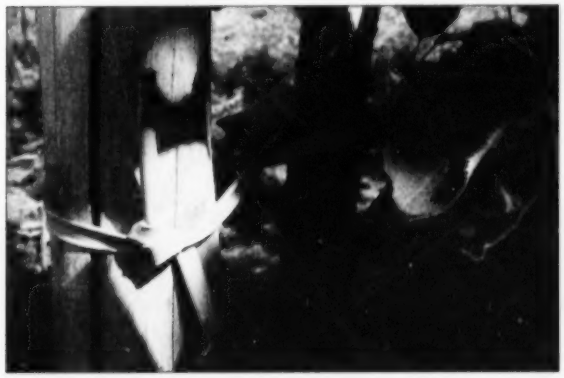


FIGURE 24. Secure the young tree to the stake with a durable tying material with high tensile strength. Draw the tree to the post with a figure-eight looping pattern. To prevent strangulation, leave enough space on the inside of the loop to accommodate an increase in trunk diameter.

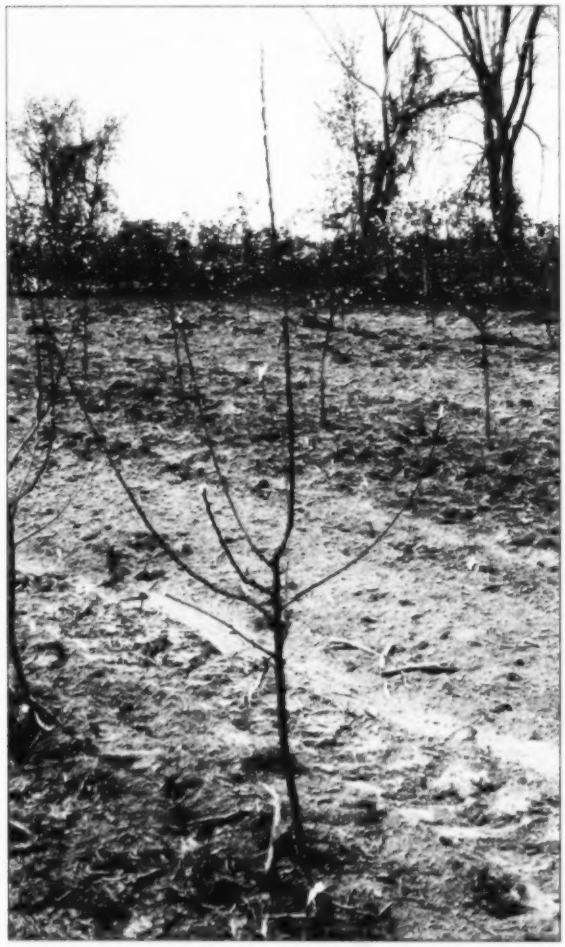


FIGURE 25. This tree has been planted as a branched 2-year-old. If well cared for, it will produce a small crop the following year. Staking and tying follow quickly after planting.

The pinching must be done several times, early in the growing season.

It is very important to emphasize growth in the planting year. The new tree should be properly secured to the support system (see Figure 24, left) and defruited at calyx to allow all trees to establish and make maximum extension growth.

Late July (after terminal bud has set)

On trees with 2-year-old lateral branches, tie down all 2-year-old branches that are longer than 45 cm to a horizontal position (vigorous varieties such as Northern Spy should be tied below horizontal). *Tying is an integral part of the SS system. Growers make money by tying to induce fruiting.* Allow limbs that are shorter to grow for the first season to get maximum extension growth. If they grow to 45 cm, tie them down in mid-August, to encourage fruit bud development. This limb positioning slows extension growth and encourages flower bud initiation followed by fruit set (see Figure 25 and Figure 26, below).

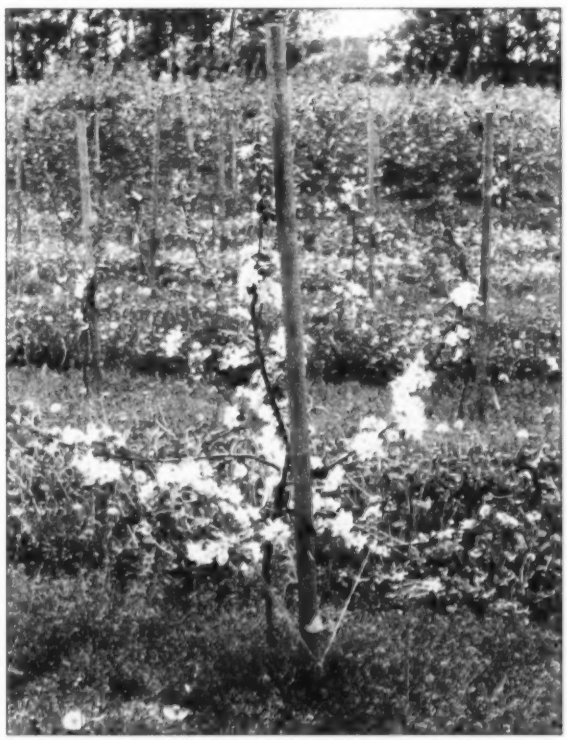


FIGURE 26. This young tree is in its second growing season after planting. It was planted as a branched 2-year-old. After one season in the field, it can be considered to be ready to crop. The lower scaffold branches have been tied into a relaxed, more horizontal position.

FIGURE 27. Dormant Pruning of Slender Spindle: Before and after photos of excessive growth in the upper middle canopy. There should not be any strong, tree-like growth in the canopy of a slender spindle bush. Arrows point to the limbs that have been removed.

September

Tie down any vigorous 1-year-old lateral branches longer than 45 cm, at the latest, before bloom the following year. Limbs are usually not tied until they are 40–45 cm long. Do not bend the lower limbs on the tree as far below horizontal as the limbs that are higher in the tree. This allows for the development of a permanent fruiting table. The easiest way to remember this is to point the branch end toward the base of the next tree trunk in the row. This limb positioning maintains the conical shape of the tree to maximize light interception and utilization.

Year Two

Dormant Pruning

Remove unwanted lateral branches using a Dutch cut (see Figure 23, on page 17), where a replacement limb is desired. If no regrowth is wanted where a limb must be removed, remove with a "flush cut." If the tree is very vigorous, wait until after bloom to remove this limb. Remove any strong, growing limbs that have a large diameter approaching that of the trunk at the point of contact and are putting the tree out of balance (see Figure 27, above). Strong growth is never fruiting growth. Even if bent, these limbs are not the best for fruit production and should be removed. Upright shoots and suckers can also be removed with a flush cut at this time.

Leader Management

In the second year, if the leader is weak, head it back. If the leader is strong, use the "head and bag" technique or bend the leader (do not head it back) so that the tip points toward the base of the next tree. If the leader is turned down to reduce growth, it must be tied back up to the stake in late June of that year. This technique results in a snaking effect.

NOTE: Where not enough branching has taken place (fewer than 4 branches) in the planting year, regrow the top. When the tree is dormant, cut the

trunk at a point 45 cm from the ground and restart the entire treetop. This seems like a drastic measure, but high-density supported systems require a "busy" tree with lots of branches. To accomplish this, the tree must be built one step at a time.

Late July and September
Proceed as in previous years.

Year Three and Later

Dormant Pruning

If there are enough lateral branches and the leader is strong, choose a 1-year-old limb as the new leader and remove the original vigorous leader. This zigzag technique of leader management keeps the leader weak. This prevents the leader from quickly reaching the top of the support stake and allows for maximum limb development lower on the tree. If the limb is too long, containment is possible by cutting into 2-year-old wood or to a fruit spur on that limb. Never cut to 1-year-old wood until the growth habits of the cultivar are studied. Most cultivars respond poorly to this cut. If a replacement leader has been selected, it must be tied back up in June.

If there is not enough branching and the leader is weak, head the leader back to encourage growth or select a superior 1-year-old branch as a new leader, tie it up and head it back.

If there is not enough branching and the leader is strong, it is possible to "head and bag" or bend the leader by pointing it down to weaken it. Remove unwanted lateral branches such as strong limbs (with a Dutch cut) as described for the second year. Remove unwanted vertical shoots and suckers with a clean cut.

Late July and September
Proceed as in previous years. Often, added support is needed on bearing branches to enable the tree to carry the crop load without damaging the tree structure or to avoid limb breakage. Some cultivars such as Gala have a fairly brittle wood. Trees capable of carrying a heavy crop load will benefit from having individual limbs tied up to the post for extra support.

Tree Training Comments

Vigour control in the slender spindle system is largely dependent upon limb positioning and early cropping (see Figure 28, right). In general, the more horizontal the orientation given to a limb, the less the extension growth that will occur. This limb will be influenced to form fruit buds and crop sooner than an unmanaged limb. Remember, once tied to the horizontal position, extension growth on the limb is virtually stopped. Limbs positioned horizontally before they have set a terminal bud will behave poorly and try to regrow vertically from the tip.

FIGURE 28. This young Spindle Bush requires attention to isolate a leader and would also benefit from repositioning or elimination of competing upright growth.

The material used for limb tying should be inexpensive, easy to knot and biodegradable by the following season. Tomato-tying twine or other jute twines have been used successfully. Tree weights at first glance appear very handy for limb positioning, but accurate weight placement on the first try is difficult. Readjustment of the weights after the limb accepts the load can be very time consuming (see Figure 29, on page 21).

FIGURE 29. An excellent example of a Spindle Bush in its third year. Fruiting has been induced by the use of tying and weighted pins. Without this technique, this Spy tree would remain largely vegetative and upright looking.

The simplest way of tying limbs is to use a separate string for each limb, tying back to the base of the post or tree. Be sure to use a loose, non-tightening loop (see Figure 30, right) when tying down limbs and do not double-wrap the limb with the string, as strangulation is possible.

Completed Knot

In post systems, another method to consider uses a continuous string going from a galvanized nail on the lower back side of the stake to a limb, then back to the nail, double-wrapped on the nail, then on to the next limb and so on, until all limbs are secured. Then the knot is tied off at the last limb.

In higher density plantings, limbs can be tied off with a tape tool to limbs on adjacent trees. This technique saves time, materials and expense (see Figure 31, right).

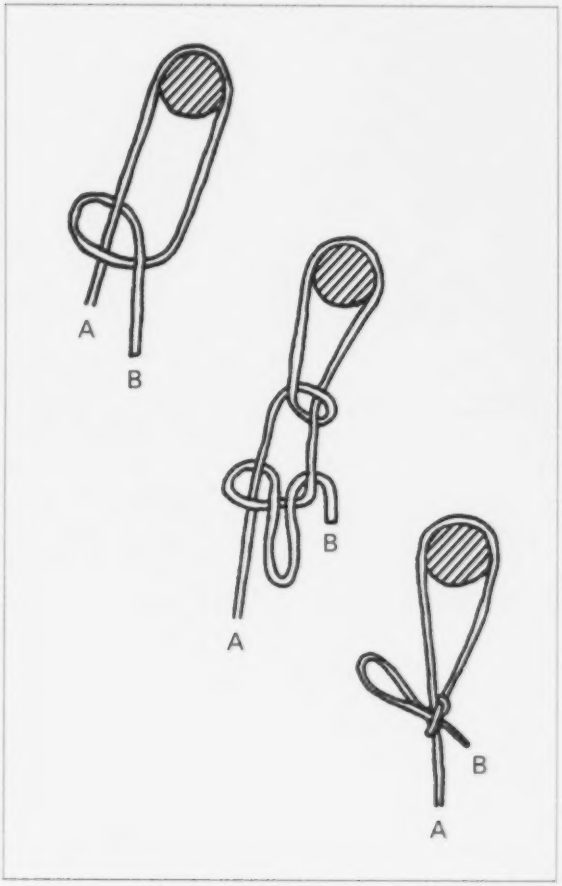


FIGURE 30. Tree Training Knot
Step 1: Secure end A to stake or tree trunk. Pass string over limb to be pulled down and pull to correct angle. Leave at least a 5-cm loop in the string before starting the knot.
Step 2: Before proceeding, pull sharply on B to transfer the loop from the B end to the A line. This prevents the knot from tightening and strangling the limb.

FIGURE 31. Limbs have been tied off to each other on adjacent trees. This simple technique results in more generative or fruiting wood in the canopy while saving on labour and material costs.

FIGURE 32. Leader snaking can help control unwanted growth in the top of a vigorously growing tree.

Rubber bands can be used to position first-year shoots. Loop the band through itself around the leader and slip the end over the shoot to be pulled down. Take care that the end of the shoot does not go too low.

Snaking of the Leader

As a slender spindle tree matures, manipulating the leader in a snaking pattern can help control top vigour. This is accomplished by tying the leader in a set position, bringing the remaining shoot around to the opposite direction and tying it down there. Eventually the top of the tree is compressed into a pattern that looks like an S-hook (see Figure 32, above).

Training and Pruning the Vertical Axis

In the vertical axis (VA) training system, a strong unheaded leader is encouraged to grow until it reaches 3–3.6 m from the ground. This central axis forms a central pivot around which lateral branches radiate to form a narrow cylinder of fruit-bearing wood. The diameter of the lateral branches gradually decreases towards the top of the tree and is always smaller than the adjoining trunk. The length of the lateral branches

FIGURE 33. A good example of a maturing vertical axis planting in Middlesex County, Ontario. Note the diffusive and open upper canopy that will enable excellent light distribution to the entire tree, from top to bottom.

also decreases from the bottom to the top. This results in a slender, conical-shaped tree. The distance between the branches decreases towards the top of the tree to allow for maximum light penetration. This system requires very little tying. The VA system can be as productive as the SS system because of the total volume of fruit-bearing surface. The orchard at maturity will form a tree wall rather than individual trees (see Figure 33, above). As with all training systems, the tree must be built one step at a time.

Year One (at planting)

Immediately after planting but while the tree is still fully dormant, head-back unbranched trees or whips to stimulate vegetative growth and bring the shoot into balance with the root system (see Figure 34, on page 23). The technique used to prune the newly planted tree in the VA system is the same as that for the slender spindle and spindle bush (see the section *Training and Pruning the Spindle Bush and Slender Spindle*, on page 16). This heading treatment is meant to encourage the development of a strong and permanent lower tier of branches. If starting with a feathered tree, refer to the discussion in the section *Year One (at Planting)*, on page 17.

Leader Development

With the VA system, the leader is pruned at planting and not touched again. In the early life of the orchard, establish a zone in each tree identified as the "production table" — the first tier of limbs. Maintain the leader in its vertical growth during the early age of the tree (especially years 1 to 8). This is

FIGURE 34. This newly planted vertical axis orchard is shown in August of the planting year. Trees have been headed back as recommended. Conduit pipe is fixed to a single wire positioned at a height equivalent to the top of the in-row posts.

best accomplished by attaching the leader to a pole and not allowing it to flex freely.

It is very important to emphasize growth in the planting year, therefore it is recommended that the trees be defruited at calyx to allow for maximum extension growth.

Pinching Technique

As soon as the new side shoots from the leader heading cut are 7–10 cm long, pinch out the growing points on the 2 or 3 competing shoots and leave the leader undisturbed. This manoeuvre encourages wide-angle crotches on any limbs developing below them and should be repeated every 14 days until the end of July. See Figure 35, right.

Allow the limbs in the production table to grow at an angle above horizontal (e.g., 45°) to make them vigorous and strong. Do not tie these limbs down. Normally, very little tying is done in VA systems. Some spreading and bending may be beneficial with some cultivars. Remove limbs lower than 60 cm above the ground. Secure the leader repeatedly to the support system to ensure maximum extension growth.

Year Two

Dormant Pruning

Keep pruning to a minimum to reduce vigour. Remove upright shoots and overpowering limbs only. Remove unwanted lateral branches using a "Dutch cut" (see Figure 23, on page 17) where a replacement limb is desired. Remove strong growing limbs as they put the tree out of balance, and strong wood is never fruiting wood. Remove limbs with a "flush cut" after bloom to prevent regrowth. Where vigour is excessive, remove limbs after they have fruited. In vigorous trees, only prune in the summer.

FIGURE 35. Shoots competing with the leader in a vertical axis system should be removed or suppressed by pinching if they originate within 30 cm of the leader. This technique is carried out early in the growing season from the second leaf when competing shoots are 7–10 cm in length.

Leader Management

Beyond the establishment year, the leader is usually not pruned or headed since maximum extension growth is desired. This is the main feature that distinguishes VA from other training systems. However, in the second year, if the leader is weak, it may be necessary to head it back. Pinch out the apical buds of any side shoots that compete with the leader every 14 days to keep them weak and encourage wide-angle crotches to form below (see the sidebar *Pinching Technique*, left and Figure 35, above). This operation begins when the competing shoots are 7–10 cm long. This technique does not require a heading cut to make it work.

NOTE: Where not enough branching has taken place (fewer than 4 branches) in the planting year, the top should be regrown. When the tree is dormant, cut the trunk at a point 45 cm from the ground, and restart the entire tree top. This seems like a drastic measure, but high-density supported systems require a "busy" tree with lots of branches. To accomplish this, the tree must be built one step at a time.

Year Three and Later

Dormant Pruning

Keep pruning to a minimum to reduce vigour. Remove upright shoots and overpowering limbs only. Remove unwanted lateral branches using a Dutch cut (see Figure 23, on page 17) where a replacement limb is desired. Remove strong growing limbs as they put the tree out of balance, and strong wood is never fruiting wood. Remove limbs with a "flush cut" after bloom to prevent regrowth. Where vigour is excessive, remove limbs after they have fruited. In vigorous trees, only prune in the summer. Secure the leader to support the system.

Fruit also controls tree height. Do not adjust (or head-back) the central leader in the VA system until fruit is at the top of the tree, and the leader has been pulled down with the weight of the fruit. At this point, perhaps year 5 or beyond, the top can be reduced in size in mid-summer to allow better light exposure to the lower limbs. No tiers of branches in the upper part of the VA are considered permanent.

As the planting gets older, it will become necessary to thin out the limbs. This thinning is done dormant and consists of removing the strongest limbs by renewal cuts (Dutch cuts) but leaving the bottom fruiting table intact. Don't begin to thin out the bottom of the tree until fruit is higher in the tree. Remember that fruiting suppresses growth, whereas, pruning encourages growth. As the tree matures, abundant fruit should be present or extension growth will be tremendous and costly to control. At maturity, summer pruning may be required for some cultivars where the upright growth is removed to allow for greater light exposure.

Trellis Systems

There are many kinds of trellis systems being used worldwide. Some are extremely formal in design and require detailed, timely management. Figure 36, below, shows an example of a V-trellis.

FIGURE 36. (A) **Before pruning** shot of Royal Gala on an established V-trellis showing a fair amount of growth in the top of the tree from the previous growing season. If left intact, the lower canopy zones of the tree will suffer from shading problems the next year.

(B) The same V-trellis **after pruning.** The top of the tree has been sufficiently thinned to allow for light penetration into the canopy. Enough fruit buds and growth have been retained in the top of the tree to keep it relatively calm during the next growing season.

FIGURE 37. A V-trellis planting system will intercept a high percentage of incoming light early in the life of the orchard. The position of the wires affects the efficiency of the picking crews.

Trellis systems involve the positioning of limbs along the supporting wires. The support wires, as a result, carry the weight of the fruit more than with the SS or VA systems. Limbs can be positioned any time the workload permits.

Horizontal positioning is the most productive, and limbs that are growing into the travel row can be either bent back in line or removed. Keep pruning to a minimum to reduce vigour. At planting, head-back the trees 15 cm above the bottom wire. Allow shoot growth to proceed unmanipulated until mid-July. At this time, secure shoots to the support lattice using quick, inexpensive tying materials. Remove upright shoots and water sprouts during August to minimize regrowth and vigour. Completion of every layer is important in a trellis system. Do not allow a strong leader to reach the top of the trellis too fast. Dormant prune to a weaker leader to delay extension. The apical bud pinching technique (described in the sidebar *Pinching Technique*, on page 23) should work well with this system. Figure 37, above, shows a V-trellis planting of Royal Gala. This system intercepts light well but can be costly to install. It can be tough to harvest the inner canopy if the wall is tight. Picking crews in some cases prefer harvesting without wires in their way as wires can slow down harvest depending on their height and position in the canopy. The Super Spindle system (see Figure 38, right) has recently attracted the attention of Ontario growers. Establishment costs can be high, with trees and their trellis components adding to the expense substantially.

FIGURE 38. Super Spindle planting demonstrates minimal in-row spacing. At a tree density of approximately 5,000 trees/ha or 2,000 trees/ac, an average of one apple per tree grown to a 100 count size would represent a yield of .82 t/ha (1 bin/ac). A well-designed system of support is necessary to compensate for the lack of structural wood in the canopy. Some cultivars are inherently better suited to Super Spindle training because of growth habit.

The Solaxe System

Some interest has been expressed in this system by growers in Ontario and Quebec. It is essentially the brainchild of French horticulturists looking for a way to control the height of the vertical axis in France. Jean-Marie Lespinasse hypothesized that if he took the best of the concept of vertical axis (which allowed the Golden Delicious cultivar to express its natural growth habit) and incorporated some of the Solen Training concept (a trellis system developed for tip-bearing cultivars, see Figure 39, on page 26), he could get better control over the ultimate height of the tree (see the section *Year Three and Later*, on page 24). By allowing a cultivar like Golden Delicious to keep growing up without heading the leader, a natural outlet for excess tree vigour is provided. However, the tree can become immensely tall.

Lespinasse decided that he would have to pull branches down below horizontal as the tree developed. When the tree got up well over 2 metres tall, he would then pull the top down as well. This

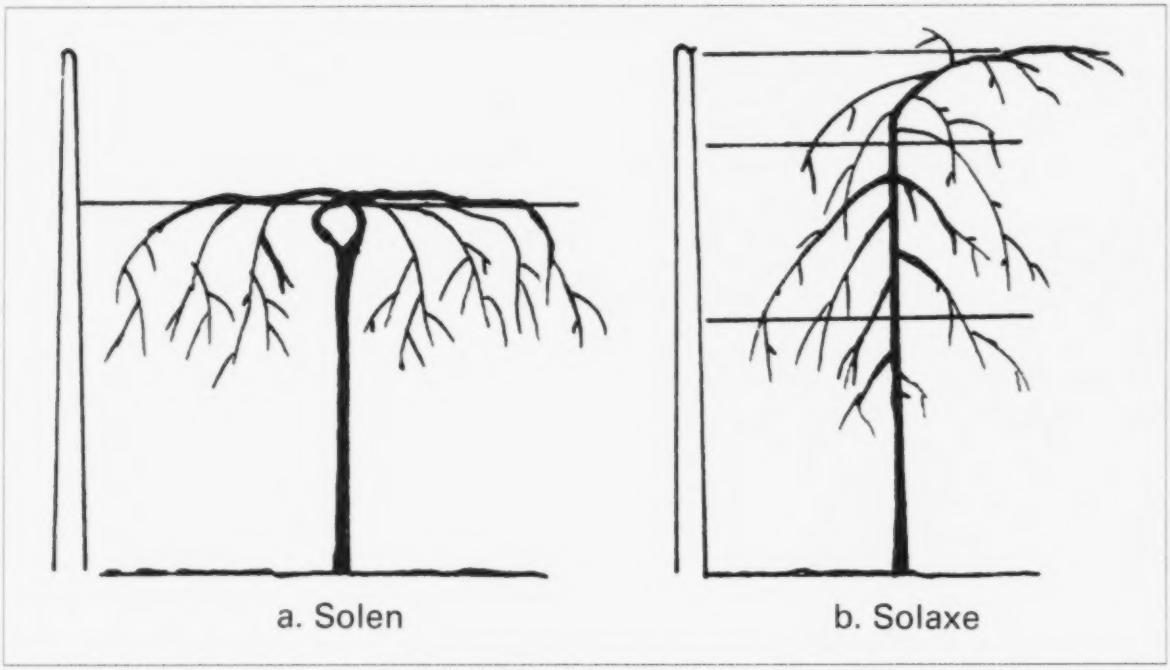


FIGURE 39. Two trellis systems: (a) The Solen, designed to handle tip-bearing cultivars and (b) The Solaxe designed to overcome the problems associated with growing a vertical axis tree too tall.

system worked. In practice, the top arm of the solaxe is formed by pulling the leader down to the top wire when it has grown 60–80 cm above.

The Solaxe system represents a much higher degree of control and manipulation than does the vertical axis system as described in this publication. The ultimate goal of the Solaxe system is to have a relaxed looking tree that requires a minimum of input once it is fruiting.

At planting, keep only feathers or branches more than 90 cm from the ground. During the first and second year, keep the trunk bud free to a height of 90 cm. Bend those vigorous upright branches to 120° from vertical shortly after planting or when they become available. Select and bend 4 shoots per year. Leave weak branches alone.

As branches develop in the second and third years after planting, pull them down below the horizontal and fix them into position by wire hooks in late summer. Once these branches begin to fruit, the weight of the crop keeps the limb down and below horizontal. This trellis system has 3 wires — one at 1–1.2 m, the second at 1.6–1.8 m and the top wire at 2–2.2 m. The hooks are made of 12-gauge wire and are less than 30 cm in length.

One of the key elements in making this system work is the removal of the growth that occurs on the top of the branches that are bent down. This growth can be sucker-like or very branch-like. The developers of this training system call this type of growth "reiterations."

With each new reiteration, the tree is stimulated to respond by producing a new root directly below the limb on which the reiteration arises. If not removed, the tree accumulates more vigour and will want to become more vegetative. Once this happens, it becomes very difficult to hold a tree in its assigned space.

By removing these reiterations in June and early July, fruit quality is improved and tree vigour is controlled. This early-season removal of this unwanted growth is essential to direct energy, water and carbohydrate flow to the fruit to maintain fruit size right to the end of the branch. The fruiting branch of the solaxe tree should have few if any secondary or tertiary branches arising from it.

Pruning Mature Trees

Prune annually to maintain trees at peak efficiency. With today's demand for high quality, most growers are pruning twice during a growing year — once when the trees are dormant and again during the growing season. Remove all rootsuckers to prevent insect problems and reduce the possibility of diseases such as fire blight having an avenue to attack root systems. Remove all vertical wood that is growing straight up in the tree or, if required, reposition it by mechanical means such as spreaders or by tying them to a more horizontal fruiting posture. Remove all broken limbs with a clean flush cut made back in healthy tissue so the wound can heal quickly. Remove all limbs that are crossing the tree and making the canopy unnecessarily crowded.

Goals

As the tree matures, the management program shifts from framework building towards four main goals:

- maintenance of canopy structure and shape to achieve uniform light distribution throughout the canopy
- maintenance of uniform vigour in the upper and lower parts of the tree
- renewal of the fruit-bearing wood to maintain a healthy, productive spur system
- elimination of crowding between adjacent trees in dense plantings

The accomplishment of these goals requires, in addition to proper pruning, careful attention to fertilization, irrigation, thinning, pest control and other cultural practices. These orchard practices will insure a healthy leaf surface and a balance between cropping and vegetative growth.

Many small pruning cuts produce a greater response in vegetative vigour than a few large cuts. In pruning mature trees, this concept can be combined with those described in previous sections to help regulate vigour within the tree.

Timing

In most circumstances, only prune mature trees during the dormant period and, where possible, after the coldest part of the winter has passed. This permits trees to achieve maximum hardiness prior to pruning and reduces the risk of exposure of pruning cuts to severe cold. Prune very vigorous trees or those requiring several very large cuts later in the season to reduce the risk of injury due to freezing.

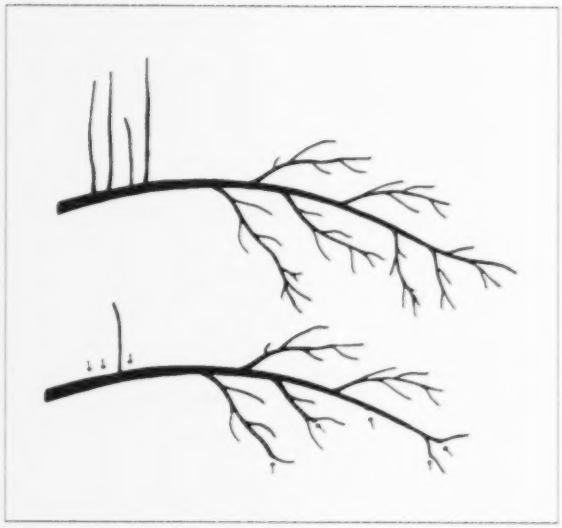


FIGURE 40. Removal of excessively vigorous growth and shaded, weaker, downward-oriented wood in mature trees (arrows mark points of cuts).

Since summer pruning results in the removal of active leaves, it may have a depressing effect on vigour. Summer pruning should be applied only in specific circumstances (see the section *Summer Pruning*, on page 29).

Control of Vegetative Vigour

Maintain a minimum of approximately 15–20 cm of annual shoot growth in the canopy of a mature tree to ensure good fruit size and provide new growth for the renewal of fruit-bearing wood removed by pruning. Maintenance of uniform vigour throughout the canopy is only possible if light distribution is also nearly uniform. Development of excessive vigour in the tops of trees can lead to increased shading of the lower canopy. Excessively vigorous wood should be removed completely (see Figure 40, above). Drooping branches that exhibit poor growth may

also shade the interior of the canopy; fruits from these branches are often undersized and of poor colour. Consequently, thin drooping wood to remove the weakest and most poorly exposed sections and help improve light exposure in the interior of the canopy.

Neglected or poorly managed trees may become spur-bound, exhibiting little or no shoot growth. This condition develops readily in older Idared and spur-type Delicious trees, although it can occur in any tree allowed to become very low in vigour. Fruit size suffers and the renewal of fruit-bearing wood becomes virtually impossible under such conditions. Thin old, multibranched spur systems to a few buds, remove some spurs and head-back others to reduce the number of growing points. Removal of approximately 30% of the buds will stimulate renewed vegetative growth. Some adjustment in the fertilization program may be necessary for trees pruned in this manner. However, fertilizer alone will not correct a spur-bound condition.

Crowding

In high-density plantings, serious problems of overcrowding can develop at any time, resulting in excessive internal canopy shading. The loss of vigour and fruitfulness in the lower part of the canopy may be followed by a corresponding increase in vigour and growth in the tops, which exacerbates the problem. Carefully control vegetative growth by fruiting, soil management and pruning to avoid this problem.

Where crowding creates a problem, design the pruning program to control, rather than stimulate, vegetative growth. Therefore, remove entire limbs with a few large cuts, rather than stubbing each undesirable shoot. Use only thinning-out cuts to avoid stimulation of vegetative growth. Because of the limited tolerance for growth between trees in dense plantings, any stimulation of vegetative growth is likely to rapidly restore the previous crowding condition.

A substantial effort may be required to restore a suitably productive canopy for older or neglected trees (see Figure 2, on page 4). Depending on the initial condition of the trees, this process may take several years. Prior to the initiation of a renovation, carry out a careful analysis of the economic merit of the renewal program. In some cases, removal of the orchard may be preferable to the expense and effort required to correct the situation.

Summer Pruning

Summer pruning removes active leaf area, thereby reducing tree vigour. For this reason, summer pruning can be used on trees that exhibit excessive vegetative vigour or where significant improvement in colour development is desired. Trees of moderate or low vigour may be seriously weakened if a significant portion of the active leaf area is removed. Pruning from bloom to late July is much more likely to reduce overall vigour and induce renewed shoot growth than pruning later. Excessive early-season summer pruning may also inhibit flower-bud formation.

Summer pruning should be limited to two major objectives:

- control of vegetative vigour by selective removal of excessively vigorous growth
- improvement of fruit colour where excessive vegetative growth causes heavy shading in the canopy

Summer pruning is not a substitute for dormant pruning. Limit summer cuts to removal of the current season's growth (see Figure 41, right). Repeated summer-pruning cuts into older wood over several seasons will dramatically reduce the amount of fruiting wood. Consequently, leave all structural pruning until the dormant period.

Delay summer pruning until terminal buds have formed and shoot growth has ceased. This will prevent regrowth on summer-pruned shoots. However, do not postpone it until fall when trees are undergoing hardening for the winter period. The optimum time for summer pruning is in late July or August. At this time, summer pruning, unless heavy, will produce little or no regrowth. Removal of vigorous shoots and their shade will improve fruit colour development without significant interference with the hardening process.

FIGURE 41. McIntosh after summer pruning. Arrows indicate point of removal of current season's growth.

If an excessive amount of leaf surface is removed during summer pruning, fruit size will be affected. If a large area of leaf surface is removed to expose the fruit to better sunlight, colour will be enhanced but potential fruit size could be depressed. By removing excessive leaf surface, the amount of photosynthate available to enhance fruit size is reduced.

Summer pruning is risky if fire blight is in the area. In such situations, it is better to avoid summer pruning until this disease is under control as it can be spread easily by pruning tools. Fruit exposed by summer pruning during periods of intense UV activity are subject to burning in some cases.

A moderate amount of summer pruning can reduce whole canopy transpiration and may help during periods of drought where irrigation is not an option.

Special Practices

Mechanical Pruning

This type of pruning is attractive because of the savings in pruning costs. Unfortunately, experience with mechanically pruned trees has shown that the need for dormant pruning may actually increase, thus increasing pruning costs rather than lowering them.

Various types of equipment have been used to mechanically prune apple trees, from simple cutter bars to complex saws capable of very large cuts. The major drawback to all mechanical pruning of apple trees is its lack of selectivity. Mechanical pruning stubs back all branches, regardless of size. This approach can often produce an enormous vegetative growth response, resulting in heavy shading and all the negative consequences that result from it. It is essential to follow up mechanical pruning with hand pruning to thin out and remove vigorous wood and restore some balance to the canopy. Even with this traditional effort, approach mechanical pruning with considerable caution.

Using a cutter bar to shear the current season's shoots in late summer is a more easily managed approach. As with dormant mechanical pruning, however, some follow-up is necessary to eliminate undesirable stubs that will produce excessive growth the following season.

Air or hydraulically operated shears and saws can be used to partially mechanize conventional pruning. In skilled hands, this type of equipment can definitely improve pruning efficiency. However, because of the ease with which cuts can be made with this equipment, it is possible for unskilled pruners to do considerable damage in an orchard. If mechanized pruning aids are used, careful supervision of the pruning crew is essential.

Ripping

Higher-density plantings can become overcrowded quickly, as previously discussed. Cultivars that branch freely can overfill assigned space in the tree wall very soon after becoming established. For this reason, the canopy can be thinned out quite efficiently with a ripping technique in early summer or in the fall with cultivars like Gala that have more brittle wood that is easily broken. The focus here is on vigorous upright or out-of-place current season's growth. This technique works best before the branch is considered to be set or well socketed. The ripping technique separates cell clusters rather than dissecting them as with a pruning cut. There may be some advantage in terms of resisting infection by wood-rotting organisms.

Resetting Mature Limbs

Occasionally it becomes necessary to reposition a fairly mature limb that for all intents and purposes is set in position. If the limb has some flexibility and can be easily grasped, it can be manipulated into a more relaxed position. After grasping the limb, twist and lower it until a distinct cracking sound is heard. The limb is stressed sufficiently along its length so that it settles into a more preferred orientation. This process is usually carried out in the spring of the year when the cambium is most active. As the breaking damage heals, the limb will remain in its newly assigned space.

Pinching

This technique is used in early summer on shoots or branches that a grower does not want to extend or grow to maturity. Shoots are pinched by removing or twisting the soft end or tip of the branch at about 10 cm of growth. This slight bruising has a dramatic effect on checking the further growth of the shoot. Unpinched shoots in the same canopy will remain dominant and continue to grow.

APPENDIX A.
Cultivar Adaptation Notes

Cultivar	Growth Habit	Grower Friendliness	Special Needs/Practices
Ambrosia	Moderately vigorous Precocious Upright and spurry	Good	Does not branch as easily as Gala; similar to spur Red Delicious Limbs should be tied down early in life of tree
Braeburn	Spur-type tree Precocious	Good	Very disease prone Susceptible to mites Relatively unattractive colour, requires superior light management
Cameo™	Good vigour Precocious Highly productive Semi spur	Good	Long picking window Matures one week before Fuji Good storage potential Can become biennial
Corail™ — See Pinova			
Cortland	Productive Moderately vigorous Tip-bearer	Poor to fair	Difficult to train in higher density plantings or on a trellis system Can do well on low trellis where branches can be supported
Crispin	Vigorous Very productive, without colour requirement	Fair to good	Fruit in shaded part of canopy may be less likely to express bacterial spot disease infection — over-pruning may lead to more infection potential in wet growing conditions Lack of colour requirement enables entire crop to be picked at same time
Delicious (Red Delicious)	Varies considerably from moderate vigour to non-vigorous spur types	Fair to good	Conventional or standard strain produces a large spreading tree with extensive secondary branching while some spur types will require extra attention to detail supporting vigour and spur renewal Good colour can be difficult to obtain, therefore special attention to strain selection is worthwhile
Earligold™	Moderate vigour Can produce some blind wood	Fair to good	Appears to be suitable for high-density plantings Adaptable to vertical axis training
Empire	Weak to moderate vigour Semi-spur habit with a spreading growth Productive	Good	Renewal pruning required as tree matures to maintain fruit size and spur juvenility Colour development can be hampered or lost by lack of attention to lower canopy light distribution
Enterprise	Vigorous, very precocious High yield efficiency Carries crop well	Fair to good	Tree can be excessively vigorous on deep fertile soils with a strong root system. Has field immunity to scab and resistance to rust, mildew and blight.
Fortune	Very vigorous Upright Free-branching	Fair	Susceptible to bitterpit, fire blight Limb position may require adjusting early in the life of the tree
Fuji	Precocious Very vigorous, will branch freely from spurs and cluster bases	Fair	Growth can be controlled in part by heavy annual cropping but must thin (early) to 5%–10% of bloom in order to return crop the following year. Fruit quality can diminish rapidly if trees are under-thinned or water starved Heavy crop load will diminish fruit colour and delay maturity Requires extra attention to light management systems for colour and sugar development Early limb positioning is important

APPENDIX A.
Cultivar Adaptation Notes

Cultivar	Growth Habit	Grower Friendliness	Special Needs/Practices
Gala	Moderate, precocious, productive Multipick	Good Highly adaptable to various planting systems	Wood can be brittle, narrow crotches or heavy crop load can lead to breakage Dependent on thinning and irrigation for best size distribution and fruiting wood development Branches freely with high output of bourse shoots, dards and brindles Highly suitable for higher density plantings
Ginger Gold™	Medium to high vigour Willowy and spreading Precocious Productive	Moderate to good	Weeping habit necessitates keeping fruiting branches at least 60 cm from the ground Susceptibility to mildew may require a more open canopy and selective pruning
Golden Delicious (and strains)	Moderate vigour Precocious, productive	Very good Adaptable to a variety of planting systems	Requires good thinning program for best quality size and colour development and avoidance of biennial bearing No serious limitations regarding planting density
Golden Supreme®	Very vigorous Upright habit Some blind wood	Fair to good	Tendency toward alternate bearing Requires good harvest management skills, as fruit will drop as it matures
Goldrush	Moderate vigour Upright with limited branching Heavily spurred	Good	Tree has a strong tendency to produce a central leader Good candidate for columnar training systems in higher density plantings
Golden Russet	Moderately vigorous Tip-bearing	Poor to fair	Tree would be very difficult to train in higher density plantings or on a trellis system
Honeycrisp™	Weak to average precocity and vigour	Fair	Requires a root system and growing conditions that will enhance the tree vigour Mature trees may require extra light management techniques to even out maturity and colour development Prone to premature fruit drop, very susceptible to bitterpit Multi-pick cultivar Heavy crop loads will diminish fruit colour Highly biennial
Idared	Moderately vigorous Precocious and heavy annual bearer	Good	Train and prune for reduction in fire blight and mildew infection probability
Jerseymac	Precocious Moderate Standard habit	Good	Leaves and fruit very susceptible to apple scab, prune for ease of spray coverage
Jonagold	Very good precocity Vigorous semi-spur habit More than 70 strains available worldwide	Good	Growers should plant best colouring strain possible based on marketability (blush vs. stripe) Loss of colour highly probably under poor pruning regime, harvest must proceed quickly as storage quality can be lost on tree Control of vigour necessary to buffer tendency for calcium-related disorders, including bitterpit
Jonamac	Moderately vigorous	Fair to good	Thinning required to improve fruit size

APPENDIX A.
Cultivar Adaptation Notes

Cultivar	Growth Habit	Grower Friendliness	Special Needs/Practices
McIntosh (and strains)	Varies considerably Reversion to standard growth habit from spur type can be problematic	Fair to good Pioneer™ Mac has a semi-spur habit and is considered to be more friendly	Colour depends on direct light exposure of the skin – a highly rated strain is no substitute for good light management practices Prone to preharvest fruit drop
Mutsu (See Crispin)			
Northern Spy	Very vigorous, upright and slow to bear	Poor	Requires high degree of input of material, labour and expense to maintain a bearing habit Untrained trees difficult to fruit profitably unless limbs in relaxed position
Paulared	Tip-bearer primarily Tree is upright, spreading and vigorous	Fair	Pruning and training programs have to fit with higher susceptibility to fire blight and mildew Tough to train in confined space
Pinova aka Corail™ and Sonata™	Low to medium vigour Very productive	Good	Blooms in mid-season Golden Delicious Empire excellent as a pollinator variety for Pinova
Red Delicious (See Delicious)			
Shizuka	Similar to Mutsu Moderate vigour Spreading with stiff branches and spurs	Fair to good	Not as tough to confine as Mutsu A triploid Worthy of trial where blister spot is problematic Suitable for vertical axis
Silken	Precocious Moderately vigorous and spreading	Good	Tendency to set heavy and requires judicious thinning
Sinta	Moderate Precocious Tree spreading, heavy branching	Fair to good	Tree difficult to train to slender form Blind wood can be a problem
Sonata™ — See Pinova			
Spartan	Vigorous, productive Upright and relatively easy to train	Good	Pre-harvest drop can be a problem Tree must be well thinned and crop easily accessible for rapid harvesting
Sunrise	Moderate vigour Extremely precocious Very productive	Good	Large crop loads make tree support necessary Crop load management necessary

Glossary of Terms

Apical Dominance — the tendency of the actively growing shoot tip to suppress the growth and development of buds and branches below it.

Auxins — plant hormones generated in the shoot tip or in young leaves and developing embryos, largely responsible for apical dominance, cell enlargement. They may induce abscission of young fruitlets or retard abscission of mature fruit.

Bed System — a system with more than one row of trees managed, for cultural practices, essentially as one row or a single unit.

Blind Wood — branches characterized by an absence of leaf growth or bud development along a portion of their length.

Bourse — swollen area at the base of a fruiting bud capable of sending out a generative fruiting branch while supporting a maturing apple.

Bourse Shoot — a shoot growing from a bourse. Can typically end in a fruit bud.

Brindle — a thin shoot of varying length arising off a branch. Can typically end in a fruit bud.

Cambium — a thin layer of meristematic cells between the xylem and phloem.

Central Leader — vertical central branch in the upper tree canopy that forms an axis around which side branches grow.

Cluster Base — the swollen area just below the flower structure, similar to a bourse. This structure is persistent and may carry fruit or leaf buds.

Crop and Flop — method of tree training that relies on fruiting characteristics and the weight of growing fruit of certain cultivars to pull branches down and into a relaxed position. The system relies on the removal of dominant upright growth, thinning-out cuts, and no tipping of fruit-bearing branches. Works best where trees are not confined to a small volume of space and are allowed to grow more in their natural habit.

Dutch Cut — a pruning cut that starts close to the trunk and angles out at the bottom of the cut allowing a dormant bud to break, creating a renewal branch.

Feathered — a nursery tree that has produced both side shoots and a central stem during the first growing season after budding.

Free Branching — readily producing abundant branches including brindles, dards, bourse shoots.

Free-Standing — unsupported tree.

Free-Standing Central Leader — unsupported tree with a distinct and dominant central leader.

Generative — having the ability to flower and set fruit.

Heading Cut — also known as a heading-back cut — a pruning cut that removes only a portion of the branch.

High Density — orchard plantings consisting of 500 trees per acre or greater.

High-Tech — describes a training system based on distinct and acute bending of the central axis or trunk of the tree to create an S-shape.

Light Distribution — amount and quality of light getting to specific zones and surfaces within the tree canopy.

Light Interception — usually referred to as the percentage of total sunlight that does not strike the orchard floor.

Pruning — the highly definitive process of shoot and limb removal by cutting or sawing.

Reiteration — Terminology used to describe growth arising from the top of the arc formed when

a branch is fixed below horizontal. It will presumably stimulate unwanted root growth and tree vigour if not removed. Can become branched and tree-like.

Scion — the stem section used in grafting that becomes the aerial part of a tree. In a mature tree, refers to all of the growth above the union.

Slender Spindle (SS) — a more narrow and pyramidal tree form than the spindle bush, generally restricted to approximately 1 metre total spread and not more than 2 metres tall.

Snaking — manipulation and tying of the leader to create an S-shape growth, presumably to control top vigour.

Solaxe — a system of training that relies on bending or fixing branches to wires in a trellis system to give the tree a weeping appearance. The top of the mature tree is bent to a wire fixed at a height of 2.2 metres. Upright growth arising from arced branches (referred to as "reiteration") is removed as it arises.

Solen — a system of tree training developed in France for tip-bearing varieties. Trees are characterized by two permanent scaffolds extending horizontally (one each way) at about 1.3 metres and supported by two closely spaced wires. Shoots that develop from these scaffolds are bent downward. The system relies on continual renewing of fruiting branches. The two permanent scaffolds are started in the opposite direction to their final orientation along the trellis.

Spindle Bush — a compact, largely conic-shaped tree typically found in higher-density supported plantings. This tree has no specific arrangement of branches and is characterized by fruit borne on short branches. Its most important feature is the tying-down of lateral shoots into a relaxed horizontal position.

Spur — a short, projecting growth carrying bourses and typically ending in fruit buds. A spur is generally considered to have a restricted growth habit.

Spur-Type — a growth habit characterized by a preponderance of spur growth while sacrificing branch initiation and growth.

Sucker — a shoot arising from an adventitious bud on a root. Sometimes referred to as a vigorous and upright water sprout in the tree canopy.

Super Spindle — a tree form adapted to very narrow and minimal in-row spacings.

Thinning-Out Cut — a pruning cut made at the point of origin of a branch.

Tip-Bearing — Growth characteristic of cultivars considered to flower and fruit predominatnly at shoot tips rather than on spurs.

Training — directing tree function and growth by limb and shoot manipulation without removing growing points.

Trellis — planting system that incorporates a post and wire configuration, usually in a vertical plane or angled outwards with more than a single length of wire supporting the tree and its branch growth. Wires can also provide a point of attachment for branches that are repositioned.

Vertical Axis (VA) — also referred to as "vertical axe," a training system resulting in a tall narrow tree dominated by a central axis supported by a single stake or pole normally supported at the top by a single wire. Fruiting branches are essentially prevented from becoming scaffolding.

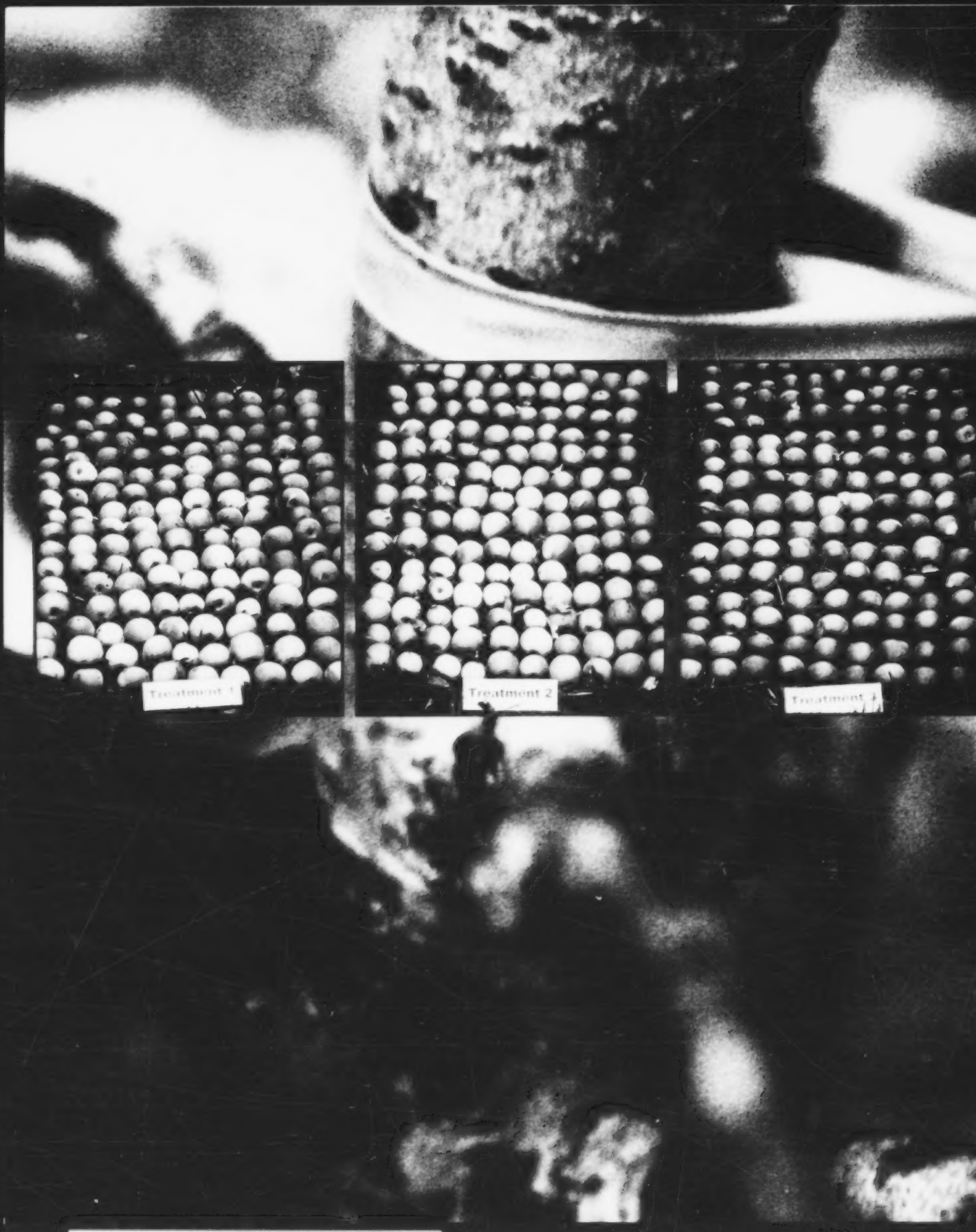
Vegetative — a tree condition that results in leaf and shoot growth without flowering and fruit set.

Water Sprout — a vigorous shoot arising primarily from latent buds on the trunk or from older scaffold branches, in contrast to root suckers, which arise from roots and trunk below the ground surface.

Whip — a nursery tree that has been grown without any evidence of side shoots or feathers and remains unbranched.

V-Trellis — a trellis system that has the trees in a single row angled out alternatively from a centre line to form a canopy that is shaped like a V.

Y-Trellis — a trellis system based on training individual trees to grow in the shape of a Y.



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